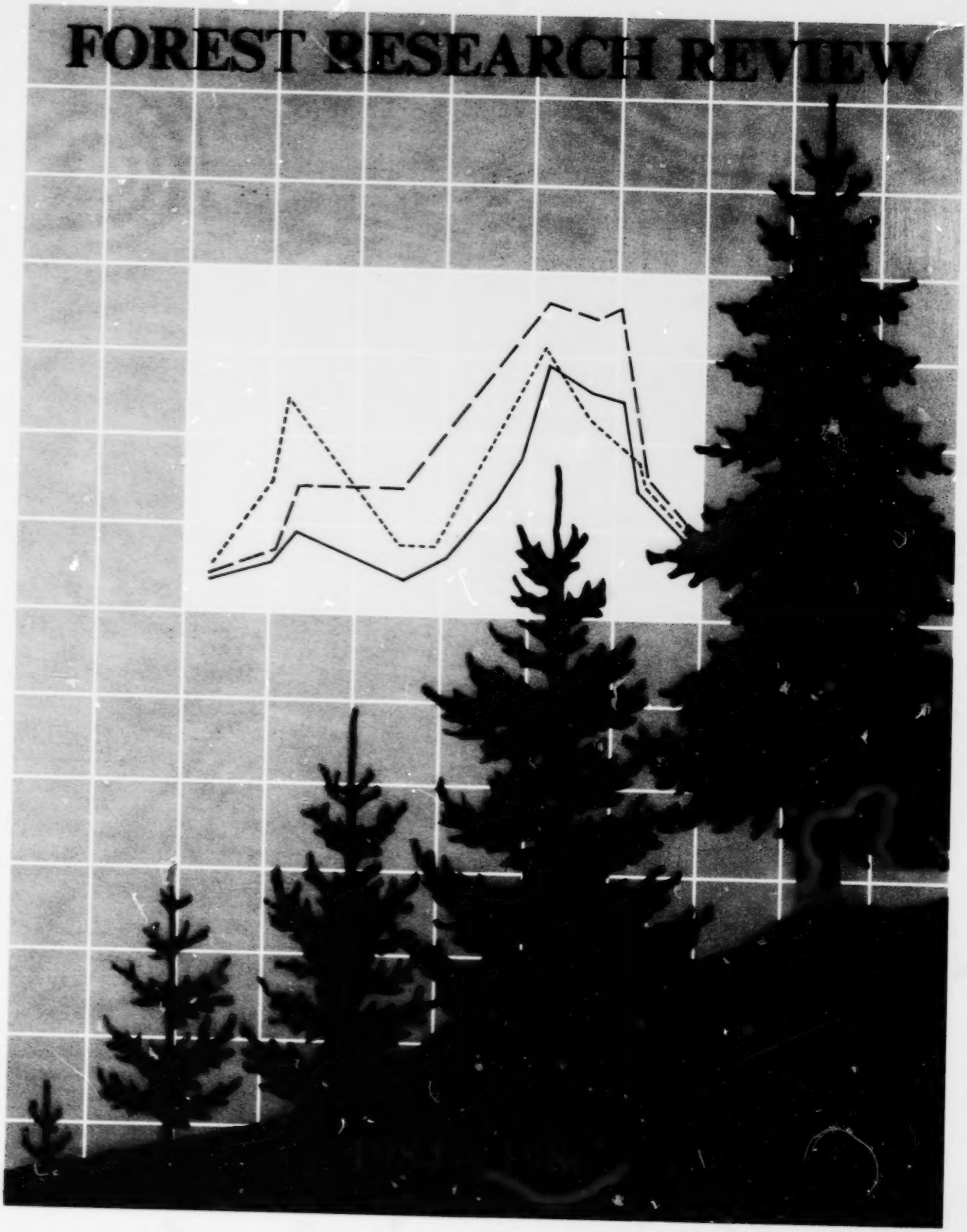
FOREST RESEARCH REVIEW



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FOREST RESEARCH REVIEW

1984 - 1986

A report of the highlights of the
Ministry of Forests and Lands Research Program

BC Ministry of Forests
and Lands

In August 1986 the B.C. Ministry of Forests was amalgamated with the Lands Division of the B.C. Ministry of Lands, Parks and Housing, creating the B.C. Ministry of Forests and Lands.

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DIRECTOR'S REPORT 1984/1986

This issue of the *Forest Research Review* marks the 30th anniversary of the inception of this series in 1956. To paraphrase from the foreword of the then Director, Mr. R.H. Spilsbury, the Review was intended to meet the perceived need for information and to foster a more co-ordinated, co-operative approach "... among individuals and organizations doing research ... particularly in the Pacific Northwest." The report has appeared annually until 1985, when circumstances conspired to delay publication to the point where production of the present report for the 2 years, 1984-1986, seemed advisable.

In the course of the Review's 30-year span, its format and content have been modified to reflect program growth and client needs. It is perhaps timely at this anniversary for us to reflect on the need for information and co-operation, and on the extent to which the *Forest Research Review* continues to contribute in its present form to these aims. Readers are, therefore, urged to participate in the enclosed survey to assess these questions.

In March 1985, the Director of the Branch, Dr. J. A. Dangerfield, resigned to become Director of the National Program for Forintek Canada Corp. While his absence is felt, his contribution to the Research Program are well recognized and will be maintained.

Staffing levels and the effective level of internal funding for operations both dropped slightly since the last report, as shown by the summarized total expenditures ($ millions):

	1984/85	1985/86
Headquarters research	6.1*	6.3
Regional research	2.4	2.6
Section 88(licensee)	0.5	0.5
Agreements**	0.7	1.8
Program fulltime equivalents (FTE's)	184	172

During the past 2 years personal service contracts increased from 61 to 147. An effort has been made to develop a stronger capability within the Branch for publications, extension services and training, which more realistically reflects the increasing client demand for information and technology. Though yet modest, these changes have enabled greatly increased productivity toward this aspect of our mandate, including a diverse range of publications, as well as workshops, courses, seminars, and conferences. During this same period, staff presented 52 conference papers, published 40 papers in refereed journals; and prepared 35 published reports and 84 unpublished special purpose reports documenting research results. In excess of 1000 individuals from government and industry were trained in a wide range of topics, such as ecosystem identification and use in forest and range management, hydroseeding in erosion control, and determining cone and seed maturity for harvest timing. In 1984/85, staff at Cowichan Lake Research Station propagated a total of 30 500 grafts of nine major tree species for the Coastal (16 500) and Interior (14 000) Tree Improvement Programs. In 1985/86, they propagated 16 300 grafts—6650 and 9650 in the Coastal and Interior programs, respectively. In supporting the nursery and seed orchard operations and specific research projects, the Analytical Laboratory conducted analyses on 16 000 soil and foliar samples. Research staff from headquarters, regional offices and the research stations hosted a wide range of visitors during the period of this report.

Research in support of the Ministry of Forests Harvesting Program primarily addresses issues or problems that affect the harvesting of the timber resource. The approach has been to develop interagency co-operative research programs to focus on these problems. Both the 5-year Queen Charlotte Islands Fish/Forestry Interaction Program and the 6-year Integrated Wildlife Intensive Forestry Research program on Vancouver Island are nearing completion. In addition to these major projects, hydrologists are continuing to investigate the impact of harvesting on domestic water supply.

The largest effort during 1984-1986 has been directed to supporting the Seed Operations, Nursery Operations, Basic Silviculture, and Intensive Silviculture activities in the Silviculture Program. In support of Seed Operations, 15-year results of an extensive series of provenance tests enabled an important revision of seed transfer rules and seed zone boundaries for lodgepole pine. Second-generation selection and grafting began for genetically improved coastal Douglas-fir seed orchards, and good progress was made in the establishment of progeny tests and breeding arboreta of the main interior species.

In Nursery Operations, pilot scale performance monitoring of white spruce was continued. This physiological testing is expected to lead to more cost effective seedling production. At the same time, in keeping with the priority placed on white spruce in

*Includes $ 0.2 million in contributions from the B.C. Ministry of Environment and Canada Department of Fisheries and Oceans for the jointly funded Queen Charlotte Islands Fish/Forestry Interaction Program.

** Major sources of funding derived from agreements between the Government of Canada and the Province of British Columbia, comprising the Intensive Forest Management Subsidiary Agreement (IFMSA) and its successor, the Forest Resource Development Agreement (FRDA).

the provincial regeneration program, work in Basic Silviculture research continued in the multidisciplinary ecophysiology project. This research is aimed at developing a fundamental understanding of the response of white spruce seedlings to environmental stress encountered on the outplanting site. In this way, research staff expect to improve the ability to prescribe site preparation treatments.

Among the varied programs of silviculture research, work focussed on acquiring a better understanding of plantation establishment problems with white spruce in the Prince George Forest Region. To address the critical need for growth and yield information, results from older established experiments throughout the province were analysed and reported, and a major espacement and thinning study was planted at Red Rock. As well, there was special emphasis on installing high-quality vegetation management research trials, using standard Research Branch testing protocols.

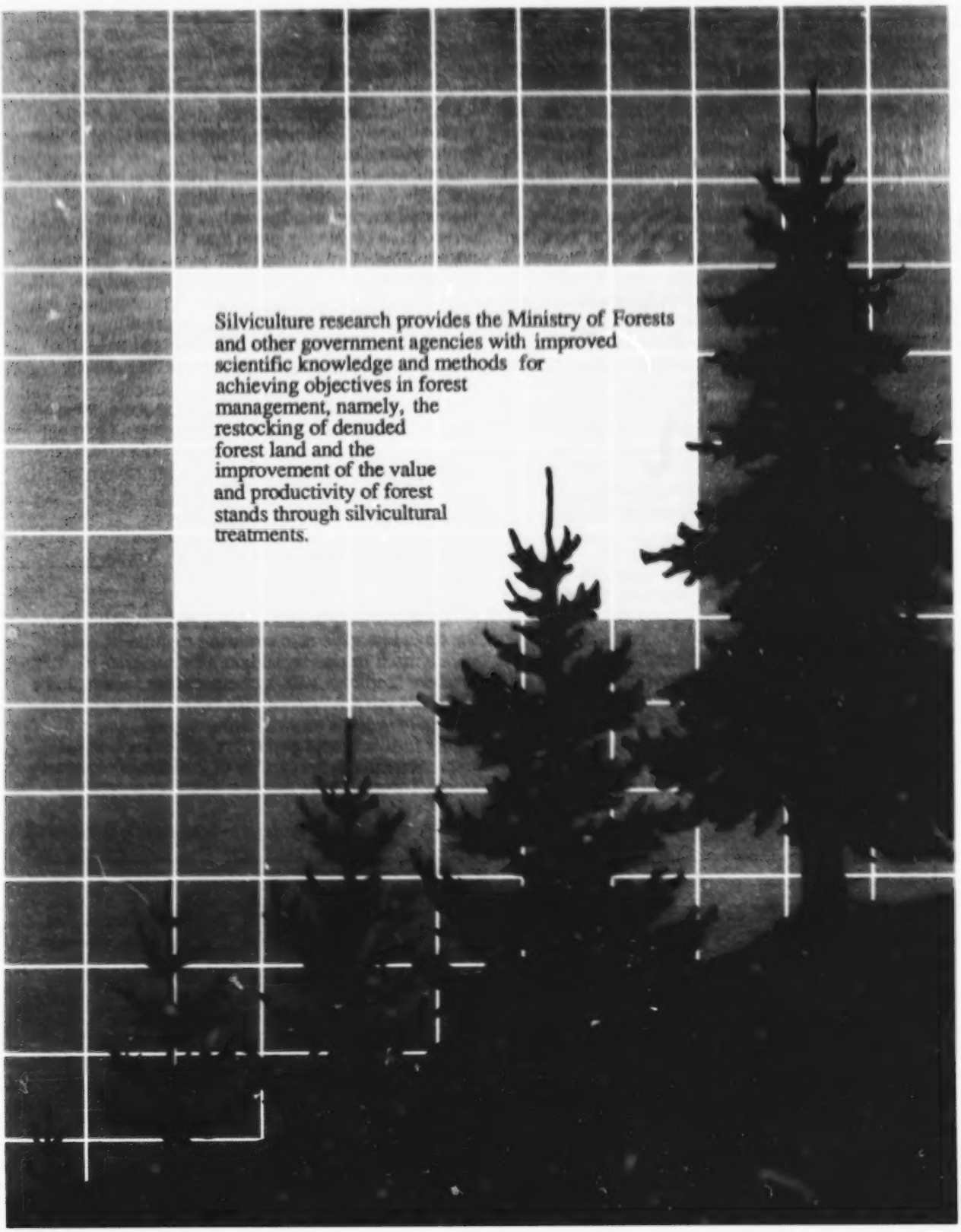
Research in support of the Range Management program was begun in knapweed control, and continued in the range fertilization project.

In addition to the quality of its science, an effective research program must focus on client needs and be capable of responding quickly to changing demands, challenges, and opportunities. A major development during the past years provides an indication of changes required.This was the signing in May 1985 of the Canada-British Columbia Forest Resource Development Agreement (FRDA). It provides funding to a total of $300 million over a 5-year period (1986-1990), primarily to ensure the rehabilitation of the backlog of "unsatisfactorily restocked", denuded forest land. A total of $27 million is allocated for extension, demonstration, and research and development on related problems in support of this goal by both governments. Of this, $22 million is being implemented and administered by the Province, $14.5 million specifically addressing "backlog-related" problems. Other components of this agreement will provide needed impetus to the long-neglected growth and yield program as well as providing for welcome updating of research facilities.

An infusion of funds in these proportions clearly presents an enormous opportunity as well as a challenge. Implications to the overall research program are: the increased emphasis on site rehabilitation and regeneration research; the increased commitment of scientific staff to research planning, management, and administration associated with a vastly increased level of contract research; and much increased opportunities for communications and extension. The challenge is to maintain the necessary integrity of our internal research program in the face of these demands.

K. Illingworth
Director

SILVICULTURE RESEARCH



Silviculture research provides the Ministry of Forests and other government agencies with improved scientific knowledge and methods for achieving objectives in forest management, namely, the restocking of denuded forest land and the improvement of the value and productivity of forest stands through silvicultural treatments.

Seed and Nursery Operations Research

*The Interior Spruce Monitoring Program**

Efforts to improve regeneration success and cost-efficiency in operational seedling production were coordinated in an interior spruce monitoring program established in 1984/85. The program, conducted cooperatively by Research Branch and Silviculture Branch, consisted of four projects: 1) the operational assessment of seedling potential; 2) the operational assessment of seedling performance after planting; 3) the experimental assessment of seedling potential and performance after planting; and 4) the assessment of loss of seedling potential during handling. Results from the third project were reported in 1985/86:

Research plots of 1+0 container-grown and 2+0 bareroot stock were monitored for one growing season to study the effects on field performance of stock type, root growth capacity (RGC), and fertilization at planting. At the same time as seedlings were outplanted, RGC was tested and fertilizer (0 or 40 g Osmocote per seedling, with an 18-month release) applied as a split plot. A total of 2850 seedlings (25 seedlings x 2 fertilizer levels x 19 seedlings x 3 blocks) were planted in a logged site in the Cariboo Forest Region.

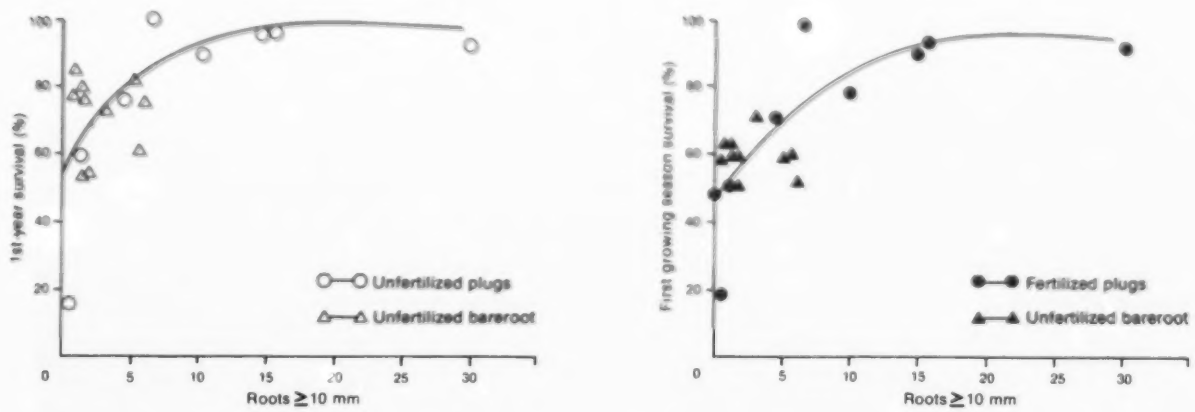
The results of the project showed that bareroot and container-grown stock types had similar survival rates, although the latter exhibited a slight (5-13%) advantage. First season height growth differences between the two stock types were substantial (3.5-4.2 cm), with container-grown seedlings showing approximately 2-2.5 times greater shoot growth than bareroot seedlings.

Increases in RGC produced increases in survival and growth of outplanted seedlings. Survival increased asymptotically, with maximum survival observed in stock having more than 10 roots (≥10 mm) per seedling. Growth was also positively affected by higher levels of RGC, particularly in container-grown seedlings, which showed a large range (0-30) in average number of new roots per seedling. By comparison, bareroot stock RGC ranged only from zero to six new roots, and growth of the seedlings was poor (2-4 cm).

Fertilization at planting (40 g Osmocote per seedling) reduced survival of container-grown (4%) and bareroot (12%) stock, but produced little effect on height growth. Little if any growth improvements, it was concluded, should be expected in the first season after fertilization at planting.

Improving the Quality of Bareroot Nursery Stock

Undercutting, lateral cutting, and wrenching are the three intensive root culturing treatments now widely used in provincial bareroot nurseries to produce seedlings with a compact root system and a high root growth capacity (RGC). Trials to test the effects of various root culturing regimes and pre-lifting fertilizer application are achieving notable improvements in the quality of 2+0 bareroot nursery stock. Three of these are described here.



Effect of root growth capacity (roots≥ 10 mm) on 1st-year survival (%). Open symbols are unfertilized, closed symbols are fertilized; circles are container grown, triangles are bareroot.

• ***Effect of Undercutting/Wrenching Regimes on Stock Quality*** **(EP 866)**

In a trial to determine the best root culturing regime for producing high-quality seedlings, undercutting and root wrenching were applied to bareroot Douglas-fir and Engelmann spruce during the first (1+0) and second (2+0) growing seasons. All four possible treatment combinations were tested: undercut-undercut, wrench-undercut, undercut-wrench, and wrench-wrench. Undercutting was done with a MacDonald Lotus undercutter, the blade of which was passed through the nursery bed approximately 10 cm below soil surface; and root wrenching was done with a standard fixed bar, passed under the nursery bed approximately 20 cm below soil surface. Both treatments were applied only once during the first growing season (mid-September), and at 7- to 10-day intervals in the second growing season (mid-July to late September). Seedling morphology (shoot length, root collar diameter, and shoot and root dry weights), pre- and post-storage RGC, and 1st-year growth of outplanted seedlings were measured.

Root culturing effects on 2+0 seedling root growth capacity in Engelmann spruce and Douglas-fir

	Root culturing treatment		Root growth capacity (new roots > 10 mm)	
	First season	Second season	Before storage[a]	After storage[b]
Engelmann spruce	Undercut	Undercut	0.1	1.5
	Wrench	Undercut	0.4	4.1
	Undercut	Wrench	0.9	3.2
	Wrench	Wrench	0.2	4.8
			(NSD)	(NSD)
Douglas-fir	Undercut	Undercut	0.2	1.5
	Wrench	Undercut	0.2	1.5
	Undercut	Wrench	0.6	3.1
	Wrench	Wrench	0.3	1.3
			(NSD)	(NSD)

[a] October 29, 1982
[b] May 13, 1983

The only morphological characteristic found to be significantly affected by the different root culturing treatments in the nursery was shoot length. For spruce, wrenching in the second growing season consistently resulted in shorter seedlings than those produced by undercutting. The RGC did not differ significantly ($p \leq 0.05$) among the treatments. That it did increase in all cases during the overwinter storage period (late October to mid-May) indicates that pre-storage measurements of RGC are poor predictors of stock quality, given that changes can occur during this time.

For both species, first season shoot growth after outplanting was significantly influenced by root culturing treatments. In spruce, wrenching in the second growth season produced taller seedlings than did undercutting—a trend opposite that which occurred in the nursery bed. This better growth by the short, wrenched seedlings was attributed to their early growth stoppage in the nursery bed, and thus longer time to initiate needle primordia and stems.

Because the four treatments produced little difference in form and field performance of seedlings, it was concluded that the choice of a root culturing regime should be based primarily on relative cost and ease of application. For 2+0 spruce seedlings, the wrench-wrench regime is recommended; for 2+0 Douglas-fir, the wrench-wrench or one of the 1st-year undercutting regimes is recommended.

• ***Effect of Nursery Environment on Stock Quality*** **(EP 836)**

Variations in the morphology and physiology of seedlings from the same provenance, but grown at different nurseries, prompted an investigation into the relative effects of nursery climate and soil on RGC, frost hardiness, and field performance. At the Ministry's nurseries in Skimikin and Red Rock, a reciprocal soil transfer experiment was carried out

Root culturing effects on 2+0 morphology in Engelmann spruce and Douglas-fir

	Root culturing treatment				Dry Weight (g)	
	First season	Second season	Shoot length (mm)	Root collar (mm)	Shoot	Root
Engelmann spruce	Undercut	Undercut	225.8[a]	4.01	2.38	1.03
	Wrench	Undercut	220.3[a]	4.05	2.31	1.05
	Undercut	Wrench	198.0[b]	3.94	2.14	1.12
	Wrench	Wrench	204.5[b]	4.02	2.10	1.14
			($p \leq 0.05$)	(NSD)	(NSD)	(NSD)
Douglas-fir	Undercut	Undercut	323.2[ab]	4.79	3.31	1.26
	Wrench	Undercut	347.1[a]	4.77	3.91	1.39
	Undercut	Wrench	310.8[b]	5.04	3.60	1.46
	Wrench	Wrench	326.9[ab]	4.84	3.30	1.29
			($p \leq 0.05$)	(NSD)	(NSD)	(NSD)

[a,b] *Within columns, values followed by the same letter are not significantly different at* $p \leq 0.05$.

with white spruce and lodgepole pine seedlings. One field plot and two raised nursery beds containing local soil were prepared at each nursery. All six beds were similarly treated with fertilizers, irrigation (as required to prevent moisture stress), and root undercutting during the second growing season. In late fall, all seedlings were lifted and cold-stored until spring. Pre- and post-storage RGC, foliage frost hardiness, and survival and first-season shoot growth were then measured.

The results showed that interior spruce seedlings grown at either nursery were more frost hardy than lodgepole pine seedlings. Neither pre-storage nor post-storage RGC was affected by nursery soil or nursery climate. The RGC of spruce increased during 7 months of -2°C cold storage, while the RGC of lodgepole pine was mainly unchanged or slightly lower. Survival overall was high (86-97%) and unaffected by nursery or soil. That the growth of Skimikin seedlings was notably greater than Red Rock seedlings is thought to be a result of some difference (as yet, unidentified) in the nurseries' cultural practices.

• *Effect of Shallow Conditioning and Late Fertilization on Stock Quality* (EP 866)

Shallow conditioning of seedlings, a process that involves undercutting followed by frequent wrenching, induces shoot dormancy and stimulates the production of a compact, fibrous root system. This enables successful outplanting, even during the growing season. The technique, used widely in New Zealand, Australia, and South Africa, is also applied in western North America, although the depth of operations must be greater than that used in the temperate regions of the southern hemisphere.

To compare the effect of shallow conditioning (undercutting and wrenching at 10 cm) with that of the standard conditioning regime used in British Columbia (undercutting and wrenching at 20 cm), trials were conducted on 2+0 stock in four nurseries. At the same time, the application of a complete NPK fertilizer was tested. Species included in the experiment, in addition to white and Engelmann spruce, were lodgepole pine, interior and coastal Douglas-fir, and Sitka spruce.

The treatments involved either shallow or standard conditioning, with one of three levels of fertilizer—0, 1.25, or 2.50 g of 4-12-8 fertilizer per seedling—applied approximately 50 days before lifting. With shallow conditioning, seedling roots were undercut at 10 cm, and then wrenched weekly at the same depth for at least 14 weeks. The standard conditioning differed only in that roots were undercut at 20 cm. After seedlings were lifted for planting or storage, RGC, shoot length, root collar diameter, and oven-dry weight were measured from samples. Field plantings followed, and the same variables were again monitored, in addition to planting time (for coastal Douglas-fir and Sitka spruce) and depth of planting, i.e., nursery level or 5 cm deeper (for interior Douglas-fir, lodgepole pine, and white and Engelmann spruce).

The results showed that for the conifers overall, shallow conditioning combined with late fertilization improved the RGC at lifting. For the interior spruces, Sitka spruce, and interior Douglas-fir, the RGC of stored shallow-conditioned stock was at least as good as that of stored standard-conditioned stock. However, the effect of shallow conditioning on survival after field planting was minimal, and it actually reduced initial height increment in lodgepole pine and the interior spruces.

Several conclusions were drawn from the experiment:

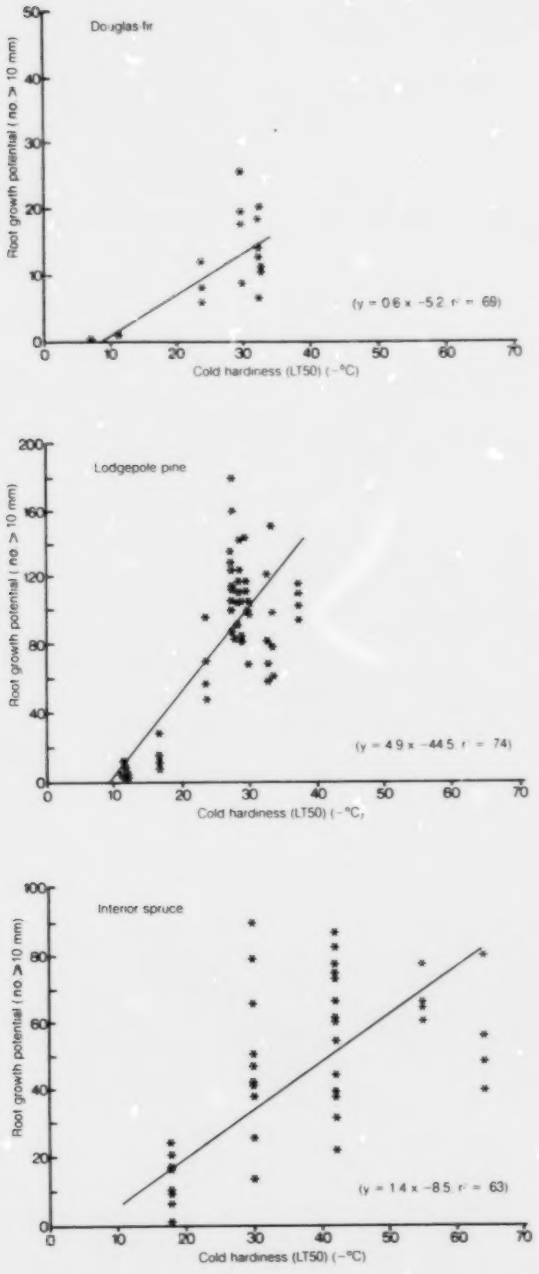
- Despite the potential for shallow conditioning to improve the RGC of conifers grown in British Columbia bareroot nurseries, the technique's value is limited by its inability to induce early cold hardiness. In any case, stock survival achieved through standard conditioning is still acceptable.
- Late fertilizer applications in the nursery can improve a plant's early growth without adversely affecting survival. Type and rate of fertilization for each species must be further studied.
- Deep planting of seedlings (approximately 5 cm more than in the nursery) is recommended for interior species to improve their field establishment.
- Autumn planting of Sitka spruce appears to be acceptable for plantation establishment on the west coast of British Columbia.

Measuring Cold Hardiness (EP 869)

With the rapid expansion of British Columbia's forest nursery industry in the last 15 years, cold storage is often required for stock awaiting outplanting. Fall or early-winter lifting, followed by cold or frozen storage for 4-8 months, is commonly carried out in the province. Crucial to the success of this practice, however, is ensuring that seedlings are lifted and packaged at time of maximum vigour, and that they retain this vigour during storage. Cold hardiness is one of the best indicators of conifer seedling storability.

Several experiments have been conducted with major conifer species in the province (interior spruce, lodgepole pine, and Douglas-fir) to study the relationship between pre-storage cold hardiness and post-storage seedling vigour. The trials found that good positive correlations were recorded for all three species when seedling vigour was measured as root growth potential, seedling survival after forest outplanting, or first season shoot growth. In 1982, 1983, and 1984, cold hardiness testing of operationally produced conifer seedlings from several nurseries showed that root growth potential,

measured following approximately 6 months of overwinter storage at -2°C, had a close positive relationship with pre-storage cold hardiness.


Douglas fir
Root growth potential (no > 10 mm)
Cold hardiness (LT50) (-°C)
(y = 0.6 x -5.2 r² = 69)
Lodgepole pine
Root growth potential (no > 10 mm)
Cold hardiness (LT50) (-°C)
(y = 4.9 x -44.5 r² = 74)
Interior spruce
Root growth potential (no > 10 mm)
Cold hardiness (LT50) (-°C)
(y = 1.4 x -8.5 r² = 63)

Post-storage root growth potential of seedlings as a function of pre-storage cold hardiness.

Genetics and Tree Improvement

Controlled Crossing Program (EP 670)

A program for the genetic improvement of Engelmann and white spruce began in 1966, with the aim of maximizing genetic increases in the species (measured as volume per unit of time) while retaining its broad adaptability to the range of environments included in the breeding zones. Improving the quality of traits such as stem form and branching characteristics is also under study.

In the main program, a large number of parent trees have been selected, and open-pollinated testing of these will guide the selection of clones for the 1.5-generation orchard. As well, a controlled crossing program for interior spruce is in progress, estimating genetic parameters before second-generation breeding. It involves 40 parents, 10 previously tested clones from the Prince George, Prince Rupert, and East Kootenay zones, and another 10 clones collected from eastern North America. In 1985, matings were carried out among clones from both within and between breeding units (30 selfs and 183 crosses, respectively). Several results of the crossings (shown in the table) were noteworthy.

Results of controlled crossings of interior spruce

Origin of ♀	Type of cross	Matings	Number of cones	Seeds	Filled seeds/cone	Average 1000-seed weight (g)
Prince George	Self	7	370	5 610	15 16	3 1842
	Cross	60	2 978	205 481	69 00	
	Combined	67	3 406	211 091	61 98	
East Kootenay	Self	6	305	6 133	20 11	2 7990
	Cross	46	2 269	112 215	49 46	
	Combined	52	2 574	118 348	45 98	
Prince Rupert	Self	9	593	4 382	7 41	2 4619
	Cross	42	1 962	53 136	27 08	
	Combined	51	2 555	57 526	22 52	
Eastern North America	Self	8	615	6 74.	10 96	2 7057
	Cross	35	2 232	73 066	32 74	
	Combined	43	2 847	79 807	28 03	
Totals	Self	30	1 883	22 876	12 15	2 8216
	Cross	183	9 441	443 898	47 02	
	Combined	213	11 324	466 774	41 22	

- Overall seed yield was significantly reduced by selfing. The selfed cones yielded an average of 12.15 filled seeds per cone; the outcrossed cones, an average of 46.73.
- Seed yield was greatly influenced by the geographic origin of the female parent. Female parents originating in the Prince George Selection Unit produced cones with an average yield of 61.98 filled seed per cone. By contrast, female parents from the Prince Rupert Selection Unit produced cones with an average yield of only 22.52.
- Average M (thousand) seed weight was also influenced by geographic origin.

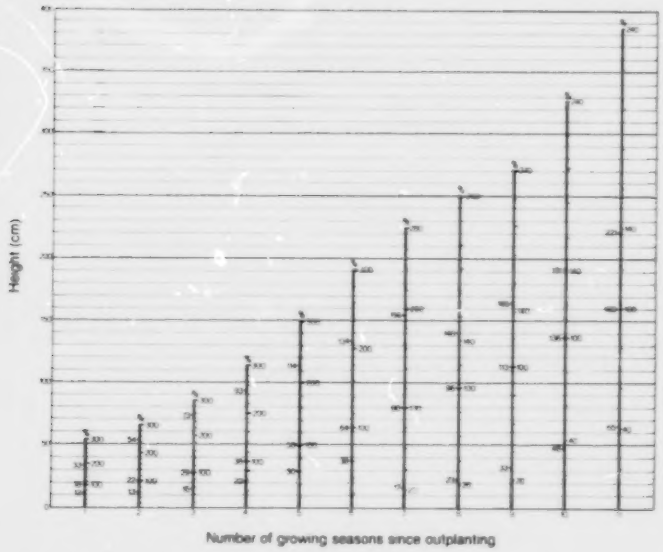
All matings for this project are expected to be completed by 1987, and plans are under way to field plant the resulting full-sib seedlings in 1989.

Forest Establishment Research

*Regeneration Performance Assessment System**

A plantation performance assessment guide for the Prince Rupert Forest Region was produced in 1984/85, the result of 3 years of field assessments in 332 operational plantations.

Based on surveys conducted within the SBSe (Moist Interior Plateau Sub-Boreal), CWHf (Northern Drier Maritime Coastal Western Hemlock), and ICHg (Northwestern Transitional Interior Cedar - Hemlock) subzones of the Prince Rupert Forest Region, height/age and height increment/age means were produced for interior spruce, Sitka spruce, hybrid spruce (Sitka X white), and lodgepole pine. A series of diagrams was created from these, showing the mean performance of the species, at given ages, in various subzones. The figure below shows a height/age diagram for interior spruce in the SBSe.



Height versus age diagram for interior spruce in the SBSe: single point evaluation.

The left-hand numbers along each vertical age bar show (from top to bottom) the maximum, average, and minimum mean plantation heights for that subzone. The right-hand numbers give a performance rating of any single plantation's height compared with the mean plantation height at a given age.

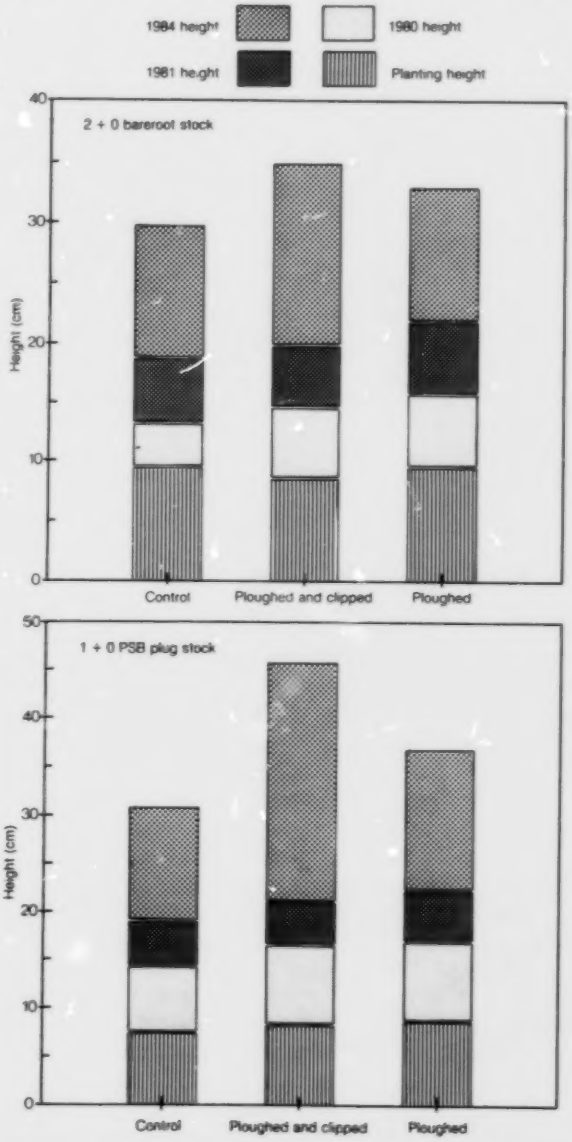
The guide provides silviculturists in the Prince Rupert Forest Region with an important tool, one which enables them to compare height performance among plantations objectively, and to determine how various height/ age and height increment/age "free-growing" standards might affect the acceptance and rejection of individual plantations.

(* No specific EP number. For further information contact J. Pollack, Research Branch.)

Effects of Mechanical Site Preparation on Seedling Survival and Growth (SX85501C)

In the Cariboo Forest Region, survival of planted seedlings on subhygric sites has often been poor because of severe vegetative competition. Shading by brush has contributed to low light intensities and cooler soil temperatures, and so hindered seedling establishment. Because these wet sites have been very difficult to broadcast burn (having a narrow burning window), and vegetation control by herbicide treatment has not been widely used in the area, mechanical site preparation currently offers the only consistent method of treatment prior to planting.

An operational silviculture trial was established in 1980 to evaluate the Caze and Heppner plough as a site preparation tool in the Cariboo River variant of



Seedling 5-year growth performance for 1+0 PSB plug stock and 2+0 bareroot stock.

the ICHh (Wet Interior Cedar-Hemlock) Subzone. The trial was undertaken by Weldwood of Canada, Williams Lake. Nine hundred interior spruce seedlings of 2+0 bareroot and 900 of 1+0 PSB-211 container plugs were planted in three site treatments—ploughed, unploughed, and ploughed and clipped—and then assessed for survival and growth. Ploughing was carried out with a modified Caze and Heppner reforestation plough. Competing vegetation was manually clipped in the ploughed and clipped treatment and soil temperature monitored in all treatments for the first two growing seasons. Survival, annual height increment, total height and survival, and seedling condition were measured after one, two, and five growing seasons in the field.

After the fifth growing season, the survival of the bareroot seedlings and plug stock in the unploughed control were 38 and 71%, respectively. Ploughing removed dense vegetative cover and exposed mineral soil with a resultant increase in soil temperature and an increase in survival of bareroot stock to 82% and plug stock to 88%. In the unploughed strips, soil temperatures were consistently 1.5-3°C lower than in the treated strips. Ploughing also significantly increased increment and total height for both stock types. Trees (bareroot and plug stock) released from vegetative competition by clipping notably outperformed those trees in the other two treatments, but only after five growing seasons in the field. Both the ploughed and ploughed with clipping treatments produced higher diameter growth, annual growth, and total growth than trees in the unploughed control. In all treatments, plug stock outperformed bareroot stock, but only marginally in the untreated control.

The results of this trial suggest that, for sites similar to the ICHh subzone in the central interior of British Columbia, the use of site preparation equipment such as the Caze and Heppner plough can help reduce the impact of severe vegetative competition.

Lorne Bedford

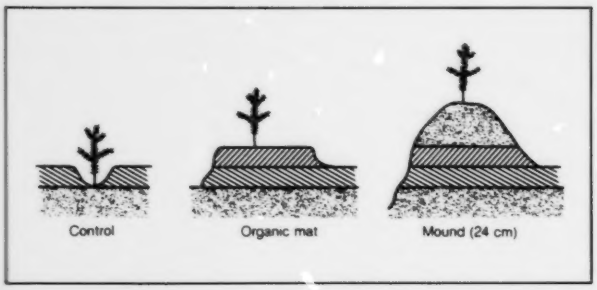
A Caze and Heppner reforestation plough.

Ecophysiology of Interior Spruce (EP 966)

Prompted by a concern for the field survival and growth performance of interior spruce (both white spruce and Engelmann spruce), the Ministry of Forests initiated research into the post-planting ecophysiology of the species in 1983. The project is aimed at studying the physiological attributes of nursery stock in the ecological context of the planting site, and it is doing this through a series of complementary ecophysiological and silvicultural investigations (including those examining mechanical site preparation, prescribed fire, chemical vegetation control, stock size, and planting data).

The sites selected for the experiments are in the Prince George Forest Region, on slopes of the Bowron River valley. Here, numerous constraints to regeneration success are represented. Excessive soil moisture, high-volume residual debris, and 15-20% slopes hinder mechanical site preparation; and low soil temperatures, limited light availability, and snow and vegetation press hinder early spruce survival and growth.

The area was classified by Research Branch ecologists as a SBSf (Very Wet Rocky Mountain Sub-Boreal Spruce Subzone) mesic shrub - devil's club-fern association, with subhygric and permesotrophic moisture and nutrient regimes. It was logged in the winter of 1981/1932 and patch scarified in August 1983. With 2+1 bareroot interior spruce as the experimental material, five microsite treatments have been carried out: control, inverted organic mat, and three levels of mineral mounding on inverted organic mats. Three of the treatments, control, organic mat, and 24-cm mounding, were intensively studied.



Schematic representation of the three intensively studied site preparation treatments.

- ***Plant Physiology Studies***

To identify those biological stresses that could potentially limit seedling survival, growth, and yield, a series of experiments was carried out to assess various physiological processes:

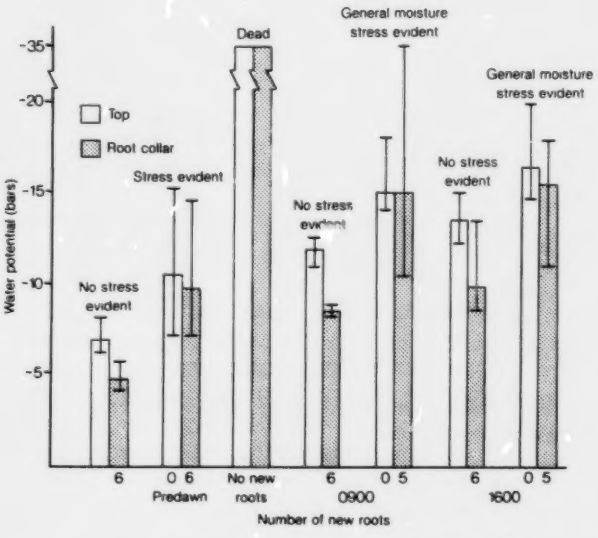
Root growth

The root growth capacity (RGC) of the planting stock used in the experiment was high at the time the seedlings were lifted from the nursery. Despite initial declines after lifting, RGC recovered during cold storage (-2°C) and was again high at outplanting, with close to 100 new roots (≥1 cm) per seedling. The root growth observed in the field varied significantly by type of site preparation, and was associated with the large differences in the accumulated number of growing degree days (>5°C) achieved by each treatment. Of the three principal treatments studied, the mound produced the greatest number of new roots (6 times that produced by the control) 1 month after planting.

Water potential

Maintenance of sufficiently high water content (turgor) is essential to normal functioning of a seedling's physiological and biochemical growth processes. Field and lab experiments of interior spruce suggest that spring and summer water potentials in healthy growing shoots should be greater than -10 bars under predawn conditions, and under -15 bars during the daytime (although variations in the latter can result from different weather conditions). Fall water potentials tend to be more negative.

When both shoot and root water potentials are measured, seedlings in non-stress conditions always show root collar values at least 2 bars less negative than their shoot values—a situation that seems to endure if six or more roots are present.



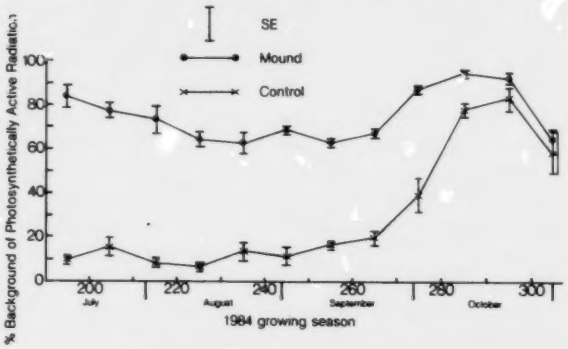
The shoot and root water potentials of interior spruce 2+0 bareroot stock.

Photosynthesis

In a field test at Red Rock Nursery, the light saturation level of interior spruce was found to be about 600μE m^{-2} s^{-1} . These results were confirmed by preliminary findings on the Prince George test site, which indicate that the light compensation point (below which no net carbon uptake occurs) was approximately 100μE m^{-2} s^{-1}.

Photosynthetically Active Radiation

Photosynthetically Active Radiation (400-700 nm) was assessed over the season at a background level (1.5 m) and at the tip of planted seedlings (approximately 360 mm above ground). The average mound seedling was exposed to light levels above light compensation point for 11 hours, or 86%, of the mean daily light period between June and September. By contrast, control seedlings were above light compensation point for only 3 hours, or 24%, of the same period. Between the photosynthetically important light saturation and light compensation thresholds, the ratio of mound to control mean daily received radiation was 5:1, and the respective ratio of duration of exposure was 3:1. This has important implications for dry matter accumulation and partitioning.



Seasonal differences in received radiation of mounding treatment and control.

Dry Matter Accumulation

Following one growing season, mound seedlings averaged 28% greater root mass than control seedlings. Observations at the time of root excavation showed that the mounded tree root systems were largely confined to the mineral capping, although in all instances some penetration of the inverted organic mat (and, in some cases, of the original *in situ* organic layer) was noted. Control tree root systems were generally limited to the plane of the planting shovel; examples of root die-back below 10 cm depth were common, and only a very few shallow and horizontally oriented new roots were discovered.

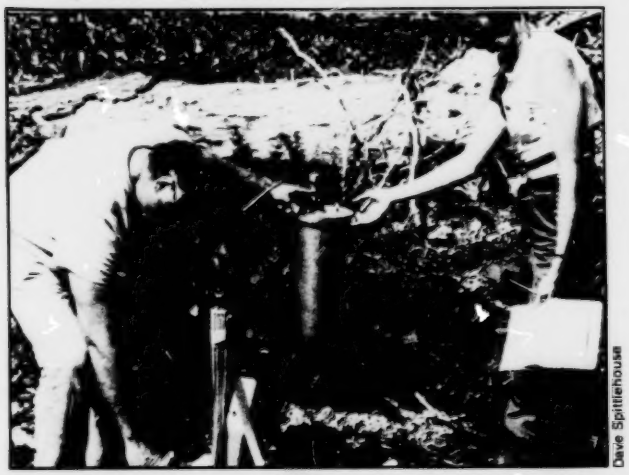
Mound seedlings produced 24% more current foliar mass in the first growing season than did control seedlings. Individual needle mass, calculated from mass per 100 needle samples, tended to increase with both the organic mat and mounding treatments over the control.

The other foliar mass fraction also showed significant site preparation effects, with mound seedlings maintaining 33% more 1st-year and older foliage than did control seedlings. Only small and non-significant differences in dry matter accumulation were found for the stem wood and bark, current branch wood, and other years' branch wood fractions considered. Nutrient concentration and content data by fraction are not yet available.

• ***Site Ecology Studies***

The ecological studies of the ecophysiology program are examining the thermal and moisture regimes of the seedling under different treatments. The variables being measured include air temperature and humidity, wind speed, rainfall and radiation above the treatments, soil temperature, soil heat flux, soil moisture, and seedling temperature at each treatment.

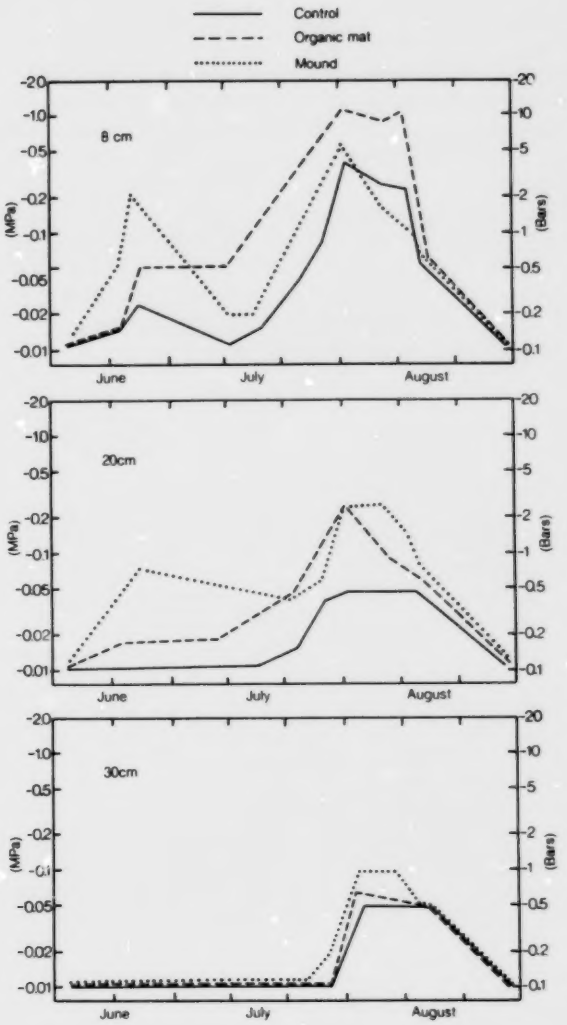
Early analysis of the data showed that during the summer dry periods, near-surface soil of the mounds and organic mat treatments dried out more than the control's, partly because of the higher evaporative demand on their unshaded surfaces. The control was notably wetter at 20 cm than the other two treatments, but all three were similar at 30 cm.



Dave Spittlehouse

Measuring seedling transpiration and water stress with a whole seedling porometer.

Soil temperature varied significantly between the different types of treatment, with the mound warming the fastest, followed by the organic mat and the control. The typical diurnal soil temperatures at 0.5 and 10 cm depth averaged 10 and 7°C greater in the mound and organic mat, respectively, than in the control. Over the first growing season, mounding tripled the number of days having a mean soil temperature greater than 10°C. On sunny days, daytime surface temperatures on the mound and organic mat varied from 25 to 60°C, depending on soil wetness and shading; and on the control, from 10 to 20°C. Winter soil temperatures fell close to 0°C, and snow temperatures around the seedling were approximately -3°C.



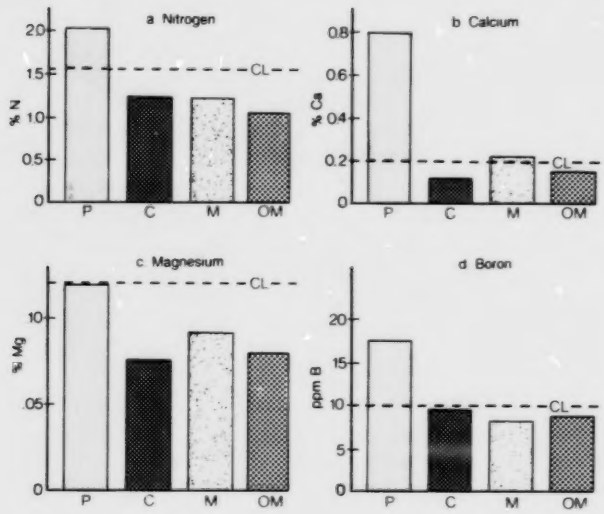
Soil water potential, June to August 1984, for the control, organic mat, and mound treatments, at 8, 20, and 30 cm.

• ***Soil Fertility and Plant Nutrition Studies***

In this component of the ecophysiology program, the nutritional status of the planted spruce seedlings is being evaluated in relation to site conditions and treatment effects.

To obtain an index of the nutrient status of the seedlings prior to planting, foliar analysis of macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (B, Cu, Fe, Mn, and Zn) was carried out on the seedlings. The same analyses were carried out upon the current foliage 1 year after planting. The foliar nutrient concentrations measured from these samples showed that despite a pre-planting abundance, deficiencies in a number of nutrients developed after one growing season. The data from October 1984 show N, Ca, and Mg to be deficient, and B marginally deficient. Nutrient monitoring is continuing.

Investigations into the mycorrhizal status of seedlings are also under way. The degree of ectomycorrhizal development and abundance of specific fungal symbionts on the roots of interior spruce seedlings are being studied at three times: before cold storage, after cold storage, and one growing season after outplanting. As well, soil characteristics are being analyzed to assess the impact of the site preparation treatments on soil fertility and subsequent plant nutrition. The various chemical and physical soil parameters measured were particle size, bulk density, pH, cation exchange capacity, exchangeable bases, available P, total C, total N, and mineralizable N.



Changes in nutrient concentrations after one growing season. P = pre-planting (May 1984); C, M, and OM = post-planting (October 1984) control, mound, and organic mat treatment, respectively; CL = critical level below which growth may be limited.

• ***Summary***

These early results demonstrate that different site preparation treatments can result in significantly different climatic and edaphic characteristics. The data, interpreted with an improved knowledge of the physiological processes on site, have led to a better understanding of the biological constraints to interior spruce survival and growth. Inverted mineral mounds alleviated some of these constraints and, provisionally, appear to offer practical advantages to the reforestation of such sites.

SITKA SPRUCE

(Picea sitchensis)

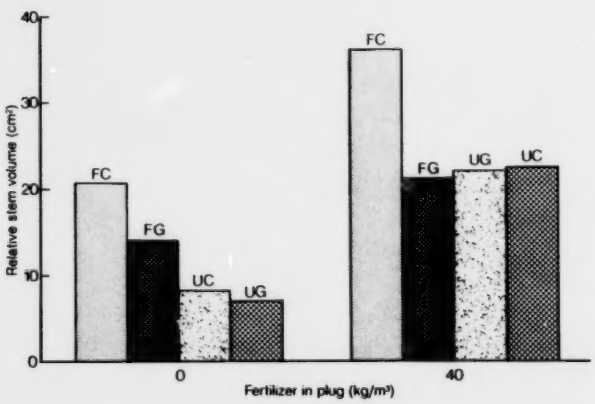
Forest Establishment Research

Effect of Slow Release Fertilizers and Vegetative Competition on Seedlings (EP 858)

In a three-way factorial experiment, second-season growth of 1+0 Sitka spruce plug seedlings was studied to determine their response to: 1) slow release fertilizer incorporated in the container growing medium; 2) slow release fertilizer distributed on the soil surface at the time of planting; and 3) grass competition.

Seedlings raised in PSB-415 containers (100-ml capacity) were used in the study. Mineral nutrients were supplied either in soluble form or by incorporation of 40 kg/m^3 of 14:14:14 (N:P:K) Nutricote slow release fertilizer (with a nominal release rate of 1 year at 25°C) into the containers' growing medium (4 g per seedling). Fertilization at time of planting was with 30 g of 18:6:12 (N:P:K) Osmocote slow release fertilizer (with a nominal release rate of 9 months at 25°C). To establish grass competition, pots were seeded with lawn grass at the time the trees were planted.

The effects of the various treatments on the second-season growth of 1+0 Sitka spruce are illustrated in the figure. Broadcast application of 30 g of Osmocote more than doubled the stem volume growth in the plugs that had not had fertilizer incorporated. Grass competition, however, reduced or eliminated the response of seedlings to broadcast fertilizer, suggesting that in the absence of competition, 4 g of fertilizer in the plug is as effective in stimulating growth as is 30 g applied broadcast. Fertilizer incorporated in the plug did not stimulate weed growth.



Effect of fertilizer and vegetative competition on second-season growth of 1+0 Sitka spruce. F = broadcast fertilizer application at time of planting; U = without broadcast fertilizer application; G = pots seeded with grass at time of planting; C = without grass seeding.

Geographic Variation in Sitka Spruce (EP 702)

The 10th-year assessment of 13 provenance test sites of Sitka spruce revealed no significant change in the pattern of geographic variation of growth and winter hardiness from that shown by earlier results. That is, southern coastal provenances grow faster but are more susceptible to winter injury than are northern inner coastal ones. The earlier recommendations—to introduce southern coastal provenances into northern sites with mild winters and to continue the use of local seeds at inner coastal valleys and high elevation sites—still stand.

Sitka spruce provenances vary not only in growth and winter hardiness, but also in their ability to withstand attack by the white pine weevil (*Pissodes strobi*). At the heavily weevil-infested Nass River trial, provenance No. 32 from Kitwanga had about 50% less weevil attack than others, and No. 62 (from Big Qualicum) also showed high degrees of resistance.

The Kitwanga provenance (No. 32), believed to be an introgressed population of white and Sitka

Sitka spruce provenance differences in white pine weevil resistance at the Nass Road test (assessed in 1984); and in winter hardiness at the Maroon Creek test (assessed in 1985)

Provenance					% Weevil-infested[a] trees (Nass Rd.)	Winter[b] injury (Maroon Cr.)
No.	Location	Lat.	Long.	Elev. (m)		
21	Yakutat, Alaska	59°31'	139°42'	12	78	0
32	Kitwanga, B.C.	55°10'	127°52'	660	42	0
44	Inverness, B.C.	54°12'	130°15'	15	75	0.3
49	Link Rd. (Q.C.I.) B.C.	53°30'	132°10'	90	97	0.2
56	Holberg, B.C.	50°37'	128°07'	30	88	0.4
61	Tahsis, B.C.	49°50'	126°40'	0	93	1.1
62	Big Qualicum, B.C.	49°23'	124°37'	0	67	0.9
03	Forks, Washington	48°04'	124°18'	135	96	0.9
12	Necanicum, Oregon	45°49'	123°46'	45	87	2.1
18	Brookings, Oregon	42°15'	124°23'	90	75	3.0

[a] Survivals were above 90% except in No. 18 (38%).
[b] 0 = no visible injury; 3 = severe winter injury (brown needles over two-thirds of the tree).

spruce, is also the hardiest: at Maroon Creek (about 20 km north of Terrace) it was one of only two provenances that did not suffer winter injury, and, further up the Nass River at Dragon Lake, the only provenance that remained free of winter injury. These results suggest that Sitka/white spruce hybrids, which combine the good growth potential of Sitka spruce with the hardiness and weevil-resistance of white spruce, may represent the best choice for planting in inner coastal valleys.

Herbicide Research Trials (EP 970)

In anticipation of increased use of herbicides to control weeds on productive forest sites in British Columbia, an interagency research co-operative was established in 1983. Its aims are to assess the potential environmental impacts—particularly on salmonids and salmon habitat—of operational applications of forestry herbicides; and to provide information for the development of environmentally conscious forest management strategies. The participants include the B.C. Ministry of Forests, the Forest Pest Management Institute and Pacific Forestry Centre (both of the Canadian Forest Service), and the Pacific Biological Station (Canada Department of Fisheries and Oceans).

In 1984, trials were conducted in the Carnation Creek Watershed on the west side of Vancouver Island and on the Skeena River floodplain between Terrace and Prince Rupert. These research locations were selected as being representative of the type of coastal plain site where intensive forest management might be practised in British Columbia. The progress of the trials at each site are summarized below:

• Carnation Creek

In addition to assessing weed efficacy and crop tree growth response to glyphosate (Roundup®) treatment, the trials at Carnation Creek included: monitoring the effects of aerial glyphosate application on salmon, salmon fry, and their use of side channels; monitoring aquatic invertebrate drift resulting from glyphosate exposure; and assessing habitat changes induced by glyphosate in streams and side channels.

In September 1984, 11 designated spray blocks in the watershed were aerially treated with Roundup at application rates between 2.0 to 2.125 kg a.i./ha. A series of environmental impact studies began immediately following the treatment. Short-term salmonid toxicity is being examined through a comparison of fish use in an oversprayed side channel to that in an unsprayed control side channel. Analysis of the data collected is now under way and study results are expected in 1985 and 1986.

• Skeena River

The research protocols proposed for the Skeena River trials were similar to those set out for the Carnation Creek trials. In addition to assessing weed efficacy and crop tree growth response to triclopyr (Garlon®) treatment, the trials included: monitoring the effects of aerial triclopyr application on salmon and salmon habitat, and on moose browse; monitoring the short- and long-term effects of herbicide and manual treatments on plant community structure and succession; and studying glyphosate aerial drift and canopy penetration to determine which delivery systems minimize off-target herbicide drift and deposit.

Although the majority of the research trials planned for the Skeena River in 1984 had to be deferred because of fishery-related concerns over the experiments, extensive preparatory work was achieved. Drift testing was completed, with three boom systems—the Microfoil Boom, the TVB, and conventional nozzles—used to apply glyphosate. Pre-spray aquatic studies, soil and litter sampling, site mapping, and vegetation measurements were also carried out on three of the research sites, in preparation for anticipated triclopyr treatments in 1985.

Herbicide trials proposed for the Peace River area, to monitor weed efficacy and crop tree response to aerial glyphosate and hexazinone, have been postponed indefinitely.

Canadian Forestry Service

Spraying glyphosate by helicopter and Microfoil Boom in the Carnation Creek Watershed.

Regeneration Research

Preventing Toppling in Lodgepole Pine Plantations (EP 791)

Toppling in trees is defined as the development of a lean, caused by rotation in the stem:root axis about a point below the ground line. It occurs in young trees, usually no more than 2-3 m high, whose slender roots are able to bend to accommodate the rotation in the root axis. Because of the curvature in the stem of a toppling tree, the leading shoot regains an upright orientation. The economic impact of toppling on a stand's value varies according to the incidence (thinnings in a managed stand with little toppling may be enough to remove most of the affected trees), as well as to the end use of the timber and the harvest and conversion methods used.

Toppling, although not common in coniferous plantations, has occurred in most British Columbia lodgepole pine plantations, its frequency varying geographically by site. In general, it affects only a small proportion of plantation trees, but in the southern Interior it appears to have a particularly high incidence. Because of lodgepole pine's high productive potential under intensive management (compared to other native species), the prevention of toppling has become an important research objective.

Previous studies have suggested that toppling in British Columbia lodgepole pine plantations results from inadequate methods of plantation establishment, rather than from an inherent weakness of the species. Even a suitable match of genotype to site may not overcome the effects on root morphology of the conventional techniques used in raising and planting forest stock. Instability may still result because most pine seedlings lose the capacity to initiate first-order lateral roots before the age at which they are usually transplanted from the nursery.

Of the techniques available to minimize the adverse effects of nursery culture and planting on root form, the most promising approach appears to be that of planting larger seedlings whose first-order lateral roots have been chemically or mechanically pruned close to the tap root. Lodgepole pine planting stock with chemically box-pruned root systems is now being used commercially in British Columbia, as well as in several other countries, and investigations of the effectiveness of this technique in preventing toppling will continue.

Effects of Grass Seeding and Cattle Grazing on Regeneration (EP 590)

Although the seeding of forest clearcuts with domestic grasses increases the forage value and carrying capacity of the forested range, its full effect on conifer regeneration is still poorly understood. To assess the long-term effects of grass seeding and cattle grazing on conifer regeneration in southern British Columbia, two studies were initiated in 1971. Their 13-year results were reported in 1985.

In one study, five clearcut blocks sown with the B.C. Forest Service's Forestland mix (timothy, orchard grass, smooth brome, crested wheatgrass, and alsike clover) were chosen for study. Sample plots were established at each site in 1984, and a species list, abundance rating, deciduous and coniferous stocking, and conifer height and diameter were recorded for each plot. Results showed that coniferous density and growth were less in seeded than in unseeded areas, although tree-grass compatability was also affected by site variability, seed source, post-logging treatments, and competition between grass and conifers and between conifers alone.

In a separate project, a 130-ha clearcut located northeast of Kamloops was planted with lodgepole pine and Engelmann spruce in the spring of 1971, and aerially sown (except for a control strip) with the Forestland mix in 1972. An exclosure was built in the area planted with lodgepole pine, and since 1976 cattle have grazed the pasture season long, at 1.2 ha per animal unit month. Pine growth parameters, tree and shrub density, understory botanical composition, and forage production were measured in 1984.

Results indicated that grass seeding did not affect pine diameter at breast height, basal area, or volume, but did moderately suppress pine height. Grazing, although it had little effect on height, did significantly benefit the other growth parameters, apparently by reducing competition from native and seeded understory species. Overall, pine growth was best on the plots that were grazed, but not seeded.

In the 13-year period since lodgepole pine had been planted, trembling aspen and willow had become major competitors with the pine saplings, and natural regeneration of Engelmann spruce and Douglas-fir was extensive. Brush densities were high for all seeding and grazing treatments. Understory composition differed little between grazed and ungrazed areas, and although three native species (orchard grass, timothy, and alsike clover) occurred frequently on the grass-seeded plots, their combined cover remained low (<15%). Total herbage production declined only slightly after the

first few years following seeding, but composition of production changed greatly, shifting from grasses to shrubs and forbs.

The results of these two studies suggest that seeding and cattle grazing can be compatible with lodgepole pine regeneration, provided that (1) pine is established before grass seeding occurs, and (2) there is good grazing management to promote the even use of forage and minimize seedling injury.

Growth and Yield Research

Stand Density Management
(WEYCO HK 009901)

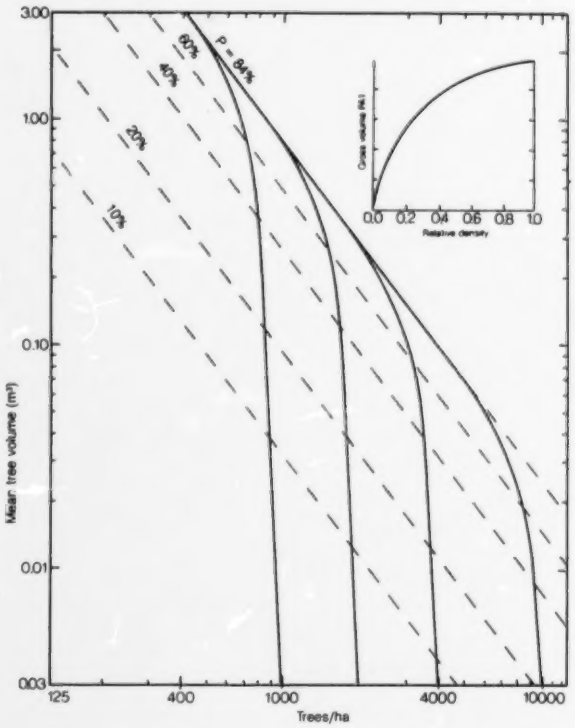
Ecological adaptability, rapid early growth, good regenerative ability, and excellent wood characteristics make lodgepole pine one of the most valuable forest resources of the British Columbia Interior. However, its tendency to regenerate overabundantly following fire or logging commonly results in excessive stand densities, which in turn reduce tree growth, vigour, and hence, merchantable volume.

Although studies have shown that lodgepole pine responds well to thinning (especially at young ages), optimum stand management regimes for British Columbia have not yet been developed, mainly because of the lack of data. Few managed stands of lodgepole pine exist in the Interior, and the generally overdense conditions in natural stands provide a poor basis for estimating potential growth rates under intensive management.

To overcome this problem, the Ministry of Forests and Weyerhaeuser Canada, Ltd., initiated a joint study that used lodgepole pine permanent sample plot data from around the world. The project involved, first, quantifying size-density tradeoffs inherent in the management of lodgepole pine; and second, estimating growth rates for the British Columbia Interior.

Twelve different sets of stand density data were assembled (five from Canada, two from Finland, two from the U.S., one from Sweden, one from New Zealand, and one from the United Kingdom), and seven growth models and two predictive mortality relationships were fitted to the data. The results of these growth and mortality analyses were then synthesized in a density management diagram, used to trace planned management regimes through a rotation.

This type of analysis offers a valuable first step toward the development of appropriate thinning strategies for lodgepole pine. As the availability of data from the Interior is improved and more work with growth modelling is carried out, the results—combined with management decisions on product size and silvicultural costs—are expected to provide important guidance in the future development of stand management regimes.



A density management diagram for use in tracing planned management regimes through a rotation. The mortality trend lines apply to both thinned and unthinned stands.

Genetics and Tree Improvement Research

Flower Production in Lodgepole Pine
(EP 657)

Fifteen years of flower production data from two clonebanks and a wind-pollinated progeny plantation at the Red Rock Nursery near Prince George have produced information to guide seed orchard site selection, seed yield projection, and seed orchard management in matters relating to pollen contamination and clonal disparity in cone production.

Results from the records suggest that:

- a managed clonal seed orchard can produce commercial quantities of seed (i.e., over 200 cones per graft) in 10 years.
- a clonal orchard may produce seeds of better quality than are produced in natural stands. (Grafts produced 44% more seeds per cone and seeds 48% heavier than did natural stands.)
- large clonal variation in both seed- and pollen-cone production occurs, and may need to be considered in orchard management.
- the differential cone production capability among provenances is inherited rather than environmentally induced. Results also show that

Comparison in number of seeds per cone and 1000-seed weight between natural and grafted lodgepole pine

Geographic region	No. seeds/cone		1000-seed weight (mg)	
	Natural stands	Grafts	Natural stands	Grafts
Yukon and Northern B.C.	22	26	2.6	4.1
Southeastern B.C. and Alberta foothills	12		3.2	
Central and Southern B.C.	16	22	2.6	3.8
Coast-Interior transition	11		2.5	
Mean	16	23	2.8	6.0
Range (provenance means)	9-31		2.2-3.9	
Range (tree or clone means)	1-66	5-39	1.4-4.6	3.3-4.9

provenances originating from northern latitudes flower earlier but are less prolific than those from southern latitudes.

Based on these results, a number of recommendations were made:

- The selection of seed orchard locations should follow similar guidelines to those established for seed transfers of lodgepole pine.
- Accordingly, the current strategy of concentrating seed orchards for the central Interior at Red Rock, and those for the southern Interior at Kalamalka (Vernon) should be maintained. This appears to be both biologically and economically appropriate, given the strong geographic trend among provenances in flower production capability.
- Seed orchards for lodgepole pine from northern British Columbia and the Yukon should not be located south of latitude 56°N, given their poor growth at many sites in the central and southern British Columbia Interior.

Seed Planning Zones and Transfer Guidelines (EP 657)

With the maturing of the Ministry's lodgepole pine provenance plots, seed transfer guidelines were reviewed and the seed zone boundaries adjusted in 1984/85. Provenance test results after 10 growing seasons have shown a broad adaptation by the species, with trees growing vigorously at sites 5° latitude north of, and 400 m above, their natural habitats.

The revised transfer guidelines incorporate both a fixed boundary and "floating principle," aimed at providing flexibility as well as administrative efficiency. The most important changes include:

- enlarging existing seed planning zones to coincide with seed orchard planning zones. This has resulted in a reduction in the number of zones from 51 to 21. The new boundaries now correspond more closely to those of the biogeoclimatic subzones within each climatic region.
- allowing a maximum 300 m in upward elevational transfer (from source) within seed zones below latitude 56°N; and a maximum 100 m within seed zones above latitude 56°N. Upward rather than downward transfer along elevation gradients is recommended. In the Interior Cedar - Hemlock Subzone, test results show that higher elevation provenances planted at lower elevations lack vigour and are more susceptible to needle cast disease. For this reason, local low-elevation seed sources are recommended for this zone.

Seed transfer guidelines along elevational gradients

Latitude	Recommended maximum transfer from source elevation (m)	
	Upwards	Downwards
57° - 60° N	100	50
49° - 56° N	300	100

- allowing, in some instances, seed transfer between planning zones with the following recommended limits: a maximum 2° latitude northward and a 1° latitude southward transfer; and a maximum 3° longitude westward and a 2° longitude eastward transfer.
- avoiding seed movement across major biogeoclimatic zones (such as dry to moist or wet, and vice versa), or from Coast-Interior transition zones into the Interior.
- avoiding seed movement of light snowbelt sources to heavy snow-belt areas, and vice versa.

Provenance Testing in the Yukon Territories (EP 657)

As part of the British Columbia lodgepole pine provenance research program, 40 provenances from north of latitude 53° were tested at Watson Lake and Whitehorse in the Yukon. Results of height growth and tree damage after 10 growing seasons were reported in 1985/86.

Data, including height growth and tree damage, were analyzed to determine the extent of influence from sites, provenances, and the interaction of the two; age-to-age correlation in growth; and variation in geographic trend. The 10-year results showed large among-provenance variation in growth, survival, and damage caused by snowshoe hare browsing. Cluster analysis separated the 40 provenances into three geographic regions: the Yukon, northeast British Columbia, and northern Alberta; central British Columbia; and coast and coast interior transition. These regions accounted for over 80% of the among-provenance variation. With the differences among geographic regions removed,

the effect of provenance latitude, longitude, and elevation were negligible.

Only trees from the northern sources grew and survived well and suffered little snowshoe hare browsing. It was therefore recommended that selection of lodgepole pine seed sources for the northern environment be limited to the very north region in the Yukon, northeast British Columbia, and northern Alberta. It was also found that any lodgepole pine provenance carrying genetic influences of the coastal variety were not capable of adapting to sites with continental climate.

Lodgepole Pine Breeding Program (EP 770)

The lodgepole pine breeding program continued in 1984/85, with selection, testing, breeding, research, and production activities in the British Columbia Interior. The basic breeding strategy involves rapid evaluation of wind-pollinated families (approximately 300 parent trees per breeding zone) to select individuals for breeding and production populations and to estimate genotype by environment interaction. Half of the trees being tested in each zone are within-zone selections, while the other half originate from: 1) selections made in or near provenances of demonstrated growth potential; and 2) zones adjacent to the zone of concern.

Ten progeny sites have now been established across four zones, and more than 500 wind-pollinated families have been grown and outplanted. By 1988, the establishment and planting of 19 sites across seven high priority zones will be complete, and will include approximately 1200 trees under test. Additional parent-tree selections made in 1985/86 will complete all first-generation selections for the seven zones.

A lodgepole pine production seed orchard was partially established in the spring of 1985 with the field grafting of the 40 best individual phenotypes of the best families from top-ranking provenances, selected in a provenance/family plantation. Various research breeding and vegetative propagation projects continue.

Nick Wheeler

Lodgepole pine crop ideotype: 85-year-old selected parent tree from the Kootenays.

The Coastal Douglas-fir Breeding Program

The Ministry of Forest's coastal Douglas-fir tree improvement program was initiated in 1957. At that time the emphasis was on intensive phenotypic selection in natural stands and the establishment of clonal seed orchards. Problems with graft incompatability in Douglas-fir led to a shift in approach in 1966, to one using wind-pollinated seedlings in the orchards. Since then, emphasis has been placed on a breeding program in which full-sib progenies from the original, wild-stand selections are being established in field trials. To date, more than 200 000 pedigree seedlings planted on 250 ha of plantations have resulted from the crossing program. These have been spread over eight annual planting "series", and stock for the eighth and last series of 11 test plantations is now being prepared for planting in 1985/86.

The overall result has been the production of abundant, high quality seed for reforestation in these first orchards—but production with limited genetic gain. In 1984/85, early selection for the establishment of a second-generation South Coast Mainland replacement orchard was begun, aimed at incorporating higher levels of genetic gain.

Provenance Trials in Coastal Douglas-fir (EP 599)

Douglas-fir occurs naturally in six biogeoclimatic subzones, but is the dominant species in only two—the CWHa (Dry Coastal Western Hemlock) and CDFb (Wet Coastal Douglas-fir)—which are present at low to mid-elevations (sea level to 700 m) on Vancouver Island and the lower coast south of latitude 51°. Because there is large environmental diversity even within these two subzones, the reforestation program has long recognized the potential biological risk in seed source displacement and the importance of seed source selection in the coastal region.

To develop appropriate seed use and transfer guidelines, a provenance program was started in the mid-1960's, and from 1968 to 1975 a network of field tests was established in four series. In Series 1, aimed at assessing the nature and pattern of geographic variation, 77 provenances were tested in five sites with contrasting climate. The 15-year results of these tests were reported in 1986.

Overall, the coastal Douglas-fir populations showed a broad pattern of geographic variation that parallels the major climatic regions, but no pattern of local adaptation was discernible. Both natural selection and chance seem to have played significant roles in shaping genetic differentiation of the species. Planting of the fast-growing seed sources, including those from Washington, in areas with strong maritime influence, was felt to offer the potential of immediate gain in volume growth, while involving little risk of climatic maladaptation. Based on this pattern of provenance variation, the following recommendations for seed transfer within the coastal Douglas-fir regions were made:

- that the Douglas-fir regions be divided into four seed zones—Wet Maritime, Dry Maritime, Central Submaritime, and Southern Submaritime;
- that two elevational bands—from sea level to 450 m and above—be imposed within each zone; and that a 200-m transfer, either upward or downward, be allowed to cross elevational bands;
- that planting Douglas-fir at elevations above 800 m be avoided; and
- that seed from the fast-growing Douglas-fir provenances found in Washington be introduced into Vancouver Island and lower coast sites having a strong maritime influence.

Early Selection Project for Second-Generation Orchards (EP 708)

Despite some risks with the limited efficiency associated with early selection, it was felt that the 6- and 7-year-old height data now available could guide the selection of suitable material and so ensure greater levels of genetic improvement than had been achieved in the existing seed sources. A double series of performance measurements was made in 1984, incorporating the 22 plantations of the original third and fourth series of crosses, and this provided an information base of 44 test sites, 33 diallel groups, 198 parent trees, 495 crosses, and approximately 88 000 trees.

Preliminary analysis of the height data shows that, overall, the additive genetic effects far outweigh the non-additive effects, and that genotype by environment interactions are relatively small, at least at this stage. Selection was based primarily on the general combining ability of the parents and the stability of parents and crosses over sites. Within-family selections were based on numerical superiority and subjective field inspections of form characteristics and performance. In general, selection against sinuosity, high branch angles, excessive lammas growth, and prolepsis was followed, with selections restricted instead to trees having straight stems with light crown forms. Selection for

adaptability was limited and wood quality was not considered at all because of the trees' young age. The selections thus made have been propagated at Cowichan Lake Research Station.

Following this initial use of the older material, information on genetic parameters and parental breeding values will be generated as the plantations become established. The next set of measures, likely taken at age 12, will provide true index selection (involving qualitative and quantitative traits) for future seed production and breeding populations. As well, the genotype by environment interactions of the widely distributed plantings are expected to guide reforestation decisions as genetically improved seed becomes available.

Meanwhile, the large collection of pedigree material established in the field tests is providing research material for a number of co-operative projects. In one, quality traits and assessment are under study, and the information will be applied in the main selection project. In another, response surfaces and genotype by environment interactions in the nursery are being examined, and the results linked to field performance. Two other research projects now in progress include tree form by site factor interactions, and the effects of lower levels of inbreeding.

Farm-Field Testing of Coastal Douglas-fir (EP 981)

Farm-field testing, a progeny test technique in which a homogeneous site is cleared and cultivated to agricultural standards, is under way at the Cowichan Lake Research Station. The technique allows tree spacing to be reduced, in turn minimizing site variation and so increasing the precision of family ranking estimates. If genotype X environment interactions remain small and family performance correlations are high, the farm-field test technique may prove to be less expensive and more efficient than other methods for future progeny testing in the Douglas-fir breeding program.

A retrospective farm-field test of 70 Douglas-fir full-sib families was established in March 1986. All 70 families are currently being tested as part of the Douglas-fir breeding program, and are represented on 11 test sites. Trees in these established test sites are 8 years older than trees in the farm-field test. The farm-field test is established at 1 X 1 m spacing, with 12 blocks and four interlocking replications per block. Each full-sib family is represented by 48 seedlings. The test design will allow two thinnings, each of which will provide trees in fully balanced experiments. Family rankings and genetic variance components will be compared between the farm-field test and the 11 standard progeny tests.

Inbreeding Effects on Growth, Seed Set, and Seed Germination (EP 982)

Inbreeding in Douglas-fir generally results in trees that exhibit reduced vigour and increased defectiveness. These negative effects have important implications for tree improvement programs, imposing a trade-off between the potential gains from selection of superior families and the losses associated with inbreeding. Thus, breeding plans and seed orchards must be designed to avoid inbreeding at levels that could reduce gain. A study to quantify the effects of different levels of inbreeding on seed set, seed germination, and growth characteristics has been initiated at Cowichan Lake Research Station.

During 1985, about 15% of the matings for this experiment were completed. Seed set results from these crosses, shown in the table below, indicate a decline with increased inbreeding. As well, induction for reproductive buds was carried out on 130 trees, through stem injections of gibberellin $A_{4/7}$($GA_{4/7}$) and root pruning. Highly successful induction treatments, combined with a cool-wet spring in 1986, allowed completion of all remaining crosses in the design (161 in total). If cone survival and seed set are adequate during 1986, sowing for this project may proceed in 1987.

1985 seed production results by inbreeding level in coastal Douglas-fir

Cross type	Fixation index	Number of crosses	Filled seeds per cone (S.D.)[a]
Outcross	0.0	20	28.9 (12.5)
Half-sib	0.125	5	19.9 (13.0)
Full-sib	0.25	3	11.7 (6.5)
Parent-progeny backcross	0.25	6	9.1 (7.9)
First generation self	0.50	8	0.9 (1.1)
Second generation self	0.75	2	0.0 —

[a] *Standard deviations based on variation between mean seeds per cone for crosses within a cross type. Mean seeds/cone within an individual cross are based on from 2 to 50 ($\bar{x} = 18.8$). Variation between cones within a cross unavailable.*

Seed and Nursery Operations Research

Effect of Heat Treatment on Flowering in Potted Douglas-fir (EP 865)

Part of a series of research projects to evaluate the cost-effectiveness of container seed orchards, a study of containerized Douglas-fir was reported in 1985/86.

Two-year-old grafts of mature Douglas-fir were potted from the field in early spring and given stem injections of gibberellin $A_{4/7}$ ($GA_{4/7}$) from the time of flushing until the end of shoot elongation. Some were left outdoors while others were moved into a heated 25°C/15°C polyethylene-covered house for the early period (to the end of shoot elongation), for a similar duration after that (the late period), or for both.

Compared to similarly potted and root-pruned grafts outdoors without $GA_{4/7}$ treatment, those that did receive the hormone showed that $GA_{4/7}$ alone increased the production of seed cones from 3 to 10 each, and pollen cones from 2 to 10 each. Furthermore, heat following $GA_{4/7}$ application doubled the production of seed cones to 21 per graft, but early heat cojointly with $GA_{4/7}$ inhibited female flowering (8 cones) and counteracted the effect of late heat in the combined treatment (15 cones). In contrast, the early and late heat treatments each significantly enhanced the production of pollen cones by the $GA_{4/7}$-treated grafts to 92 and 78 each, respectively. The best results (162 cones) resulted from the combined treatment.

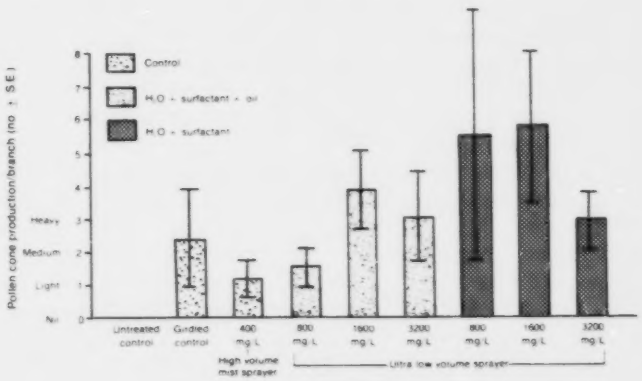
The study concluded that heat treatment of potted Douglas-fir within a "polyhouse" is an effective adjunct to $GA_{4/7}$ and root pruning (or drought) in promoting early and enhanced flowering for breeding and seed production. Moreover, its timing, a critical factor, can be used to influence the sex ratio.

Evaluation of ULV Spray Equipment for Gibberellin Application (EP 935)*

Gibberellins applied to Douglas-fir and western hemlock have been shown to enhance cone production. One conventional mode of application is by high volume (HV) mist sprayer which, in Douglas-fir, is not as effective as stem injection and, though commonly used in western hemlock, can be wasteful. An alternative is ultra low volume (ULV) spray application in which droplet size can be controlled within an optimum range (approx. 60-110 μm), to minimize evaporation and drift and maximize coverage and absorption. The use of horticultural spray oils in combination with the gibberellin $A_{4/7}$ ($GA_{4/7}$) mixture can further improve foliar absorption.

A study was conducted to test the effectiveness of ULV spray equipment in making foliar applications of $GA_{4/7}$ on seed orchard trees of Douglas-fir and western hemlock. Trees of each species received a range of treatments, varying in ULV spray type and concentration and in the use of spray oils. The Douglas-fir stems were also girdled (except for an ungirdled control). Results of the various treatments are shown in the figure below.

In Douglas-fir, ULV spraying proved to be an effective method for foliar application of $GA_{4/7}$, particularly applied with water-surfactant-oil formulations. Compared to the HV spray treatment, the water-surfactant-oil sprays resulted in 4.2 times more seed-cone buds at only 0.1 the dosage of $GA_{4/7}$ used in the HV spray. Higher concentrations of $GA_{4/7}$ did not increase female response and the highest (3200 mg/L) reduced it. No phytotoxicity from spray oils used at the high concentrations was apparent.



Effect on flowering response of $GA_{4/7}$ application by HV and ULV spray equipment in Douglas-fir.

In western hemlock, ULV sprays were less successful. At the rates applied in the study, the HV spray treatment was more effective than either ULV treatment used. Even the highest ULV concentration tested (875 mg/L) was suboptimal.

The study concludes that although further tests are needed to examine the effectiveness of higher concentrations of $GA_{4/7}$ on western hemlock, for Douglas-fir ULV sprays have promising practical application in indoor potted orchards where neither wind nor rain can hinder the spraying's success.

* Study results and figures have been previously published by R.C. Bower and S.D. Ross.1986. Evaluation of ULV sprays for seed orchard applications of $GA_{4/7}$. Part 2. Proc. 20th Mtg. of the Can. Tree Improvement Assoc. F.Carson, A.G. Curriveau, and T.J.B. Boyle (editors). Can. For. Serv., pp.103-110.

Effect of Late-Season Fertilization on Mineral Nutrient Reserves (EP 640)

Bareroot Douglas-fir seedlings were given three levels of nitrogen, phosphorous, and potassium fertilization (low, medium, high) during July to October of their second growing season in a nursery. The following January seedlings were lifted, an initial sample was obtained, and the remaining seedlings were grown in a sand culture under three nutrient regimes: 1) no essential nutrients except calcium; 2) all essential nutrients except N; and 3) all essential nutrients. After 8 weeks, seedlings were separated into new shoots, needles, stems, old roots, and new roots. Dry weight and nutrient content of these parts were determined and changes during growth calculated by subtracting initial sample values. In a second similar experiment, seedlings were grown in an artificial soil in the greenhouse and harvested at 14-day intervals so that dry weight and nutrient content changes could be followed.

Seedlings increased in dry weight by 49% over 8 weeks with no net uptake of N, P, or K. During this time some 40% of the N, 30% of the P, and 44% of the K in the seedlings were retranslocated to support new shoot and root growth. In the absence of external N, P, and K supply, needles, stems, and old roots all lost these nutrients. Needles appeared to be the most important N storage site since they continued to retranslocate N in the presence of an external supply and, similarly, old roots were the important P and K storage site and retranslocated P and K when these nutrients were supplied externally.

Seedlings from high fertilizer treatment in the nursery had higher N concentrations and content than seedlings from the other two treatments. They also showed a higher relative growth rate in sand culture, but not in artificial soil. Late-season fertilization increased the number of new roots produced after 14 and 28 days, and hastened bud burst. These effects were attributed to increased mineral nutrient reserves.

Optimizing Pollen Storage Conditions (EP 773)

Despite the advances made by tree improvement programs in the production of genetically superior forest stock, poor pollen storage can inhibit the reproductive process and limit the operational implementation of superior parent trees. As a result, pollen management, involving the use of reliable methods for storing pollen and testing its viability, has become an important research focus.

Earlier trials with Douglas-fir pollen storage regimes indicated that reduced moisture content (4%) and low temperature (-26°C) could maintain pollen viability for up to 3 years. To further investigate the effects of storage conditions on pollen, however, another more extensive trial was established in 1983. It aimed at testing two storage temperatures (4°C and -26°C), four moisture contents (4, 8, 12, and 16%),two storage atmospheres (air and no air), two container types (glass serum vial and foil pouch), and four different pollen lots. A total of 128 separate pollen treatments were carried out.

One-year storage results, measured in terms of seed yield, are shown in the table below. Percentage moisture content, storage temperature, and storage atmosphere were all found to affect pollen fertility significantly. Above 12% moisture content, the fertility of stored pollen declined rapidly, particularly combined with a storage temperature of -26°C. However, pollen storage in an atmosphere of no oxygen had a beneficial effect on fertility, especially at a storage temperature of 4°C. Storage trials conducted with western hemlock pollen produced similar 1st-year results.

Effect of moisture content, storage temperature, and storage atmosphere on fertility (expressed as filled seeds per cone) of Douglas-fir pollen stored for 1 year (LSD, ± 9.1[t=.05, n=15])

Pollen moisture content	Seed yield (FSPC) (filled seeds per cone)			
	+4°C		-26°C	
(%)	Air	No air	Air	No air
4	50.6	53.2	51.6	53.2
8	46.1	43.2	40.6	46.4
12	20.4	47.7	0.1	9.6
16	1.8	19.2	0.3	0.2

Effect of moisture content, storage temperature, and storage atmosphere on fertility (expressed as filled seeds per cone) of western hemlock pollen stored for 1 year (mean values ± SE, n=8)

Pollen moisture content	Seed yield (FSPC) (filled seeds per cone)			
	+4°C		-26°C	
(%)	Air	No air	Air	No air
4	25.4 ± 1.9	26.2 ± 1.1	24.5 ± 1.6	22.8 ± 1.7
8	27.9 ± 1.2	24.5 ± 2.5	23.0 ± 2.1	22.8 ± 1.7
16	0.2 ± 0.1	26.3 ± 2.1	8.1 ± 3.1	6.0 ± 1.8

As a result of these findings, preliminary recommendations for the successful storage of Douglas-fir pollen include: 1) reducing the moisture content of pollen to between 4 and 6%; 2) using containers (glass or heat-sealed laminated foil pouches are preferred) that provide air-tight seals; and 3) maintaining a storage temperature near -26°C.

Tests are continuing on the same pollen lots to determine the 3-year effects of storage on pollen fertility.

Viability Assays for Testing Pollen Fertility (EP 773)

Efforts to develop *in vitro* viability assays for conifer pollen to determine potential field fertility have been producing good correlations with *in vivo* field tests in Research Branch trials.

Although germination is a common measure of pollen viability for Douglas-fir, the technique generally provides a poor estimate of potential fertility and yield because identifying germinating pollen grains in this species is so difficult. In recent years, however, two other assays have shown encouraging results. In respiration analysis, the rate of oxygen consumption by a pollen lot provides an overall measure of metabolic status. With the other technique, electrical conductivity of leachates is measured, providing an indication of pollen membrane integrity (high conductivity values of pollen leachate show greater degrees of membrane damage and, consequently, lower potential fertility).

Field fertility tests using the three viability assays have found that respiration shows the best correlation with seed yield, followed by conductivity. Germination was the least reliable technique for evaluating fertility, with a correlation to seed yield of only 30%.

Work to improve all of the viability assays is proceeding, and the effects of media on pollen germination and of prehydration in all assays is also under study.

Correlation coefficients between four viability assays and seed yield (filled seeds per cone and percentage of filled seeds to total seeds, n=128)

	Coefficient of correlation					
	Respiration[a]	Conductivity[b]	% Conductivity[c]	Germination[d]	Filled seeds per cone (FSPC)	% FSPC
Respiration	—	-0.68	-0.71	0.48	0.77	0.83
Conductivity	-0.68	—	0.99	-0.83	0.78	-0.82
% Conductivity	-0.71	0.99	—	-0.84	-0.81	-0.85
Germination	0.48	-0.83	-0.84	—	0.64	0.68

[a] *Respiration = μ lO_2/(min · g).*

[b] *Conductivity = μU /(25 ml · g).*

[c] *% Conductivity = (Conductivity cold/conductivity hot) x 100*

[d] *Germination = Percent pollen grains germinating ≥ 2 x diameter.*

Propagation and Seed Orchard Research

Crown Management in Douglas-fir (EP 944)

Orchard height control through crown management is used to improve the efficiency of orchard operations and increase flowering. In 1984/85, a research trial was carried out to test different crown-pruning regimes within Douglas-fir.

Seedling trees in two blocks of a 10-year-old Saanich seed orchard received three levels of top pruning factored with three levels of branch thinning, each with and without stem injections of gibberellin $A_{4/7}$ ($GA_{4/7}$). Moderate top pruning from six back to five whorls of live branches significantly depressed the production of both seed and pollen cones, as did all levels of branch thinning, which were designed to increase light penetration within the tree crown. More severe top pruning, back to three whorls of live branches, caused a further significant reduction in flowering in one of the orchard blocks. The same treatment, however, increased flowering relative to untopped controls in the other block, where trees were slightly smaller and showed less vigorous growth. While the long-term response remains to be assessed, crown training beginning at a young age appears to have potential for increasing Douglas-fir seed yields and for controlling tree size for improved efficiency of orchard management.

Trees in all treatments responded positively to stem injections of $GA_{4/7}$. Increases in seed- and pollen-cone bud production averaged 161 and 91%, respectively, although cone abortion was also 35% higher for the $GA_{4/7}$-treated trees.

Root Pruning to Induce Flowering (EP 780)

Root pruning experiments in Douglas-fir clone-banks and seed orchards have resulted in increased cone production. In a study of the long-term effects of repeated root pruning on trees, a plantation of full-sib families established in 1969 was root pruned for the first time in fall 1975. The trees were root pruned three more times: in the fall of 1978, fall of 1981, and spring of 1984.

After the first root pruning, there were some cones on the treated trees, but none on the controls. The second root pruning (in the fall of 1978) caused a heavy cone crop on the treated trees in 1980, while the controls this time showed only sporadic cone production. Following the third root pruning in the fall of 1983, the root-pruned trees again produced more cones than the controls. An assessment in 1985 indicated equal numbers of female buds on the root-pruned trees and the controls, as a response to the root pruning treatment in the spring of 1984.

With each additional root pruning, the treated trees became smaller and their crowns narrower than those of the controls. This was particularly noticeable following the fourth treatment. Because of the reduction in crown volume and cone-producing area on the treated trees, future production on untreated trees (if they have reached cone-bearing age) is expected to exceed the total past and present cone yield on the treated trees. Thus, root pruning to enhance cone production is only recommended where early production is required.

Effect of Different Understock on the Growth Rate of Grafts (EP 648)

Because the vegetative growth of scions is sometimes so rapid that ramets are too tall to use in breeding programs when the first flowering occurs, efforts to develop a "dwarf" rootstock in Douglas-fir were initiated in the mid-1970's. The aim of the research project was to find a rootstock source that would promote development of a seed orchard graft characterized by slow height growth and early cone production.

In a study of the effects of rootstock origin on scion development, 25 rootstocks from each of nine provenances were grafted with scions from 25 different coastal plus-tree clones. The provenances selected included coastal, transition, and dry interior types. From the beginning, height growth of the scions differed significantly among rootstock sources. Grafts on dry interior understock were the shortest and those on coastal understock were the tallest. Assessments of flower bud production for 1979 to 1981 revealed that scions on understock from a dry interior climate produced more flowers than those on coastal rootstocks.

After 1982, however, the pattern in cone production began to change, and in 1984 the grafts on coastal understock produced the largest number of cones. It is believed that this change occurred because the grafts on coastal understock were taller, more vigorous and had wider crowns than did the grafts on interior understock.

The study concluded that for coastal conditions there is no advantage in using an interior rootstock, which appears to reduce the size and vigour of grafts, as well as the cone production.

Don Carson

Effect of different understock on the growth rate of grafts.

Controlling Height Growth in Container Coastal Douglas-fir (SX 85201V)

It has been established that the optimum size that stock should reach before outplanting is 17.5 cm in height, with a 3-mm minimum caliper. Difficulties in controlling height growth, however, have regularly resulted in spindly trees, *Botrytis*-caused mortality, and poor outplanting performance.

In 1984/85, an operational silviculture trial was conducted, aimed at determining if drought stress and high light levels in combination might successfully control seedling growth. Blocks of 313 and 415 container seedlings underwent three stress treatments: saturation watering at 5 cm height; saturation watering at 10 cm height; and moderate watering (control). All treatment blocks were allowed a period to dry down before being resaturated, and this regime was repeated three times.

The severe moisture stress to which the container seedlings were subjected reduced overall height growth compared to the control treatment, although it did not result in increases in root weight or root collar diameter, nor did it induce bud set. Even under extreme moisture deficits, no foliar damage or mortality occurred, and such treatments appeared to reduce *Botrytis* infection.

Growth and Yield Research

Estimating Growth and Yield of Interior Dry-Belt Stands (EP 987)

The interior dry-belt of British Columbia extends throughout major parts of the Cariboo, Kamloops, and Nelson forest regions, and is characterized by an arid climate, often thin, excessively drained soils, and topography that is broken frequently by rock bluffs. Forest stands in the dry-belt are comprised mainly of uneven-aged Douglas-fir, ponderosa or yellow pine, and lodgepole pine, and they have estimated productivity rates well below the provincial average.

With a timber supply deficit predicted within 20 years for many of the Timber Supply Areas that support interior dry-belt Douglas-fir, and recent concerns of the Ministry's Planning and Inventory Branch over the validity of the yield estimates now used for interior dry-belt fir stands, a problem analysis was carried out to examine the difficulty of estimating growth and yield in the dry-belt region. In a case study, the stand-table projection method and dry-belt growth data were used to estimate periodic growth in stands following partial cutting by the faller's selection method. The results showed that if the original stand structure was to be sustained, a cutting prescription that more closely follows the original structure would have to be followed. With projected higher growth rates, the diameter class imbalances caused by logging tended to be remedied. However, even at the highest diameter growth rate tested (double that anticipated), the intensity of the original harvest could not be maintained on a 20-year cutting cycle.

In response to the report's recommendations, a number of actions have already been taken:

- research and data collected by members of the Inland Northwest Growth and Yield Cooperative (of which the Ministry of Forests is an active participant) are expected to improve growth and yield estimation capabilities for the dry-belt.
- a study to determine response to spacing in partially cut Interior Douglas-fir stands is under way in the Cariboo Forest Region.
- analysis and reporting of dry-belt interior Douglas-fir data is being carried out.

*TASS Meta-Model**

To facilitate Ministry of Forests use of managed stand yield table information generated by the TASS Douglas-fir model, a "meta-model" was developed in 1986. It is capable of generating a file of merchantable volumes, based on a range of stand ages in 1-year increments for any specified site index and any initial density, within the ranges defined in the yield tables. As well, it can generate similar files for any of the variables given in the yield tables (such as top height, mean diameter at breast height, and mean annual increment) and for the input variables, regeneration delay and years to breast height. All of this information can be produced for two precommercially thinned densities: 1110 or 500 trees per hectare.

Other features of the meta-model include its ability to determine the maximum mean annual increment and culmination age of all volume-age relationships, and to incorporate falldown factors for them; and to generate yield information that is within 1% of the tabular values for 90% of the entries.

In addition to its use with the Douglas-fir managed stand yield tables, the model is designed to accommodate similarly formatted yield tables for other species, such as lodgepole pine and white spruce.

(*No specific EP number. For further information contact K. Mitchell, Research Branch.)

Response of Coastal Douglas-fir to Precommercial Thinning (EP 554)

A correlated curve trend (CCT) project, established in 1959 in a 14-year-old Douglas-fir plantation on a medium site near Campbell River, B.C., was modified in 1966 with the addition of three replicates to parts of the spacing and thinning series of the CCT design. These new plots are being used to study the effects of precommercial thinning treatments on the growth and yield of coastal Douglas-fir. The 10 regimes differed in thinning intensity, that is, frequency (number of entries), grade (light or heavy), and timing of first entry; and ranged from no thinning (control) to heavy and frequent thinning.

In 1984/85, a 17-year assessment of the yield and increment data from the project was conducted. To date, the plots have been measured six times, at intervals of approximately 4 years. Tree condition, diameter at breast height (dbh), total height of a subsample, total volume, and total merchantable volume were recorded and summarized in stand average and per-hectare values, by plot and measurement period, for all trees and for crop trees.

Analyses, done on the basis of individual trees, crop trees, and the entire stand, showed that all of the thinning regimes tested have increased the growth of residual trees, and have also produced trees of greater merchantable volume. Individual trees, for example, at total age 38 years, showed diameter gains of 9-35% over those in non-thinned stands, and merchantable volume per tree of 65-250% over. Gradual heavy thinning, however, resulted in trees with larger diameters and diameter growth than did light or single thinnings. After thinning, absolute diameter growth was higher in the initially larger trees, but the initially smaller trees gained more proportionately. It was also found that, although "thinning shock" substantially reduced height growth immediately following the treatment, growth is now

higher in the heavily thinned plots than in those moderately thinned. Neither height nor height growth was affected by thinning.

The results of this preliminary assessment suggest that dense, young Douglas-fir on medium moist, medium rich sites in the Wetter Maritime Coastal Douglas-fir Subzone be thinned gradually before total age 30 years (where it is economically feasible) to a post-thinning density of less than 1000 stems per hectare.

Response of Red Alder to Mechanical Treatment (SX 83701V)

Red alder is one of the major impediments to the successful survival and growth of conifers on forest sites in the Vancouver Forest Region. With its rapid growth and ability to form dense stands, it often dominates recently logged areas, outcompeting conifers for growing space, light, and moisture. Herbicides are effective in controlling alder, but because many forest areas in this Region are near population centres or important bodies of water, the efficacy of non-chemical control treatments needs to be examined. Manual brushing is one of these, although the rapid resprouting of red alder after cutting has long brought into question the practicality of the treatment.

In 1983, initiated by local concerns over herbicide use, an operational trial was undertaken in Powell River, B.C., to investigate the effectiveness of manual brushing in reducing alder competition. The main objectives of the trial were: 1) to determine which of five treatment periods during the summer growing season is the most effective cutting time to minimize alder regrowth; and 2) to assess the effect of alder removal on subsequent conifer survival and growth.

A 4-year-old stand of red alder, overtopping planted Douglas-fir and grand fir seedlings, was selected for the project. The study area was divided into four blocks, two containing alder that had been manually treated in 1980, and two containing alder that was left untreated. Each was divided into six treatment plots: one uncut control, plus one plot for each of the five 3-day treatment periods between June 7 and September 1. Cutting was done with circular brush saws.

Results from two full growing season after treatment showed that alder mortality was maximized and sprout regrowth minimized on surviving stumps when alder was cut during the late growing season, August to September.

Pre-treatment survey of the operational trial site, spring 1983

		Area not manually brushed in 1980			Area manually brushed in 1980		
		Mean	S.D.	Sample size	Mean	S.D.	Sample size
Red alder	Stems/ha	4400	1700	12 plots	51600	16757	12 plots
	Diameter (cm)	3.5	0.8	262 trees	1.2	0.2	619 trees
	Height (cm)	440	88	12 trees	330	55	12 trees
Conifers							
Grand fir	Stems/ha (including natural)	220	250	12 plots	500	674	12 plots
	Height (cm) (planted only)	124	37.5	153 trees	134	45.2	122 trees
Douglas-fir	Stems/ha	1350	475	12 plots	2250	1658	12 plots
	Height (cm) (planted only)	171	53.2	339 trees	170	58.1	387 trees

Net change between total number of sprouts treated and number of sprouts developed one growing season after treatment

Treatment period[a]	Not pre-treated			Pre-treated		
	Sprouts cut 1983	Sprouts 1984	Net change	Sprouts cut 1983	Sprouts 1984	Net change
1	100	792	+ 692	450	651	+ 201
2	100	363	+ 163	470	395	- 75
3	100	317	+ 217	570	250	-320
4	100	274	+ 174	420	144	-276
5	100	108	+ 8	460	260	-200

[a] *Treatment periods: 1 = June 7-8, 1983; 2 = July 5-7, 1983; 3 = July 19-21, 1983; 4 = Aug. 2-4, 1983; 5 = Aug. 30 - Sept. 1, 1983.*

Both Douglas-fir and grand fir in the treated plots showed greater diameter increment growth than those in untreated controls one full season after treatment (1984). Alder mortality increased in all treatment periods and on control plots during 1985. Reduced conifer diameter growth and increased alder mortality is thought to be attributable to the severe moisture stress induced by low rainfall during the summer of 1985. The net result has been an increase in percentage of free-growing conifer saplings, especially on plots representing later treatment periods.

Final measurements and conclusions will follow the 1986 growing season.

Effect of Spacing on Growth, Yield, and Performance (EP 786)

In three experiments at four nurseries in coastal British Columbia, Sitka spruce, white spruce, lodgepole pine, western redcedar, and coastal and interior varieties of Douglas-fir were grown at a range of spacings within drills 15 cm apart. In a fourth experiment the frequency distribution of seed spacings achieved with three types of precision seeders was examined.

A 1-cm increase in spacing increased seedling dry weight by 0.5-1.5 g and root collar diameter by 0.2-0.25 mm, up to a spacing of about 8-10 cm. Above this spacing, response was less. Height of 2-year-old (2-0) seedlings was increased little or even decreased by wider spacing. Height:diameter ratios decreased sharply and shoot:root dry weight ratios decreased or remained unchanged with wider spacing. In 2-0 Douglas-fir buds, the number of needle primordia increased up to a spacing of 2 cm,

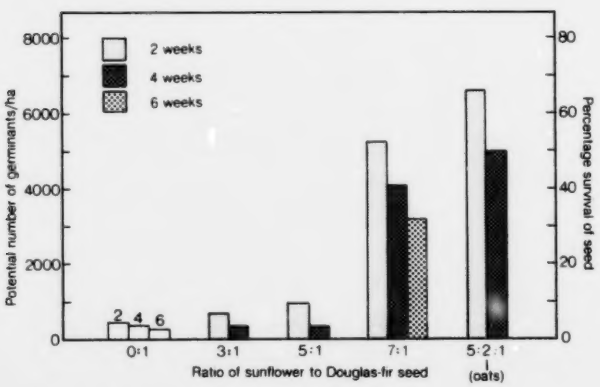
and the number of first- and second-order branches also increased with wider spacing. Needle dry weight and area measurements suggested Douglas-fir from wider spacing had more sun type needles than those from closer spacing, which had more shade type needles. Only small increases in root growth capacity were associated with wider spacing. None of the precision seeders tested achieved perfect precision of seed placement. With irregularity added by 10-20% non-viable seed and winter mortality, truly precision-spaced stands of 2-0 seedlings could not be achieved under existing conditions. Increased spacing of 2-5 cm between seedlings, depending on species and nursery, was justified by yield of acceptable seedlings when culling standard was increased to a root collar diameter of about 6 mm.

Three years after planting, survival of white spruce was increased 11% by wider spacing in the nursery; the corresponding value for Sitka spruce 2 years after planting was 13%. Seedlings of both species maintained a height and diameter advantage from wider spacing, over those from close spacing.

Forest Establishment Research

Operational Direct Seeding with Alternative Foods (EP 839)

The problem of conifer seed predation by rodents and birds has long hindered the success of direct seeding programs in British Columbia. To address this problem, a biological technique using alternative foods in direct seeding has been developed for Douglas-fir in coastal regions and lodgepole pine in interior regions.



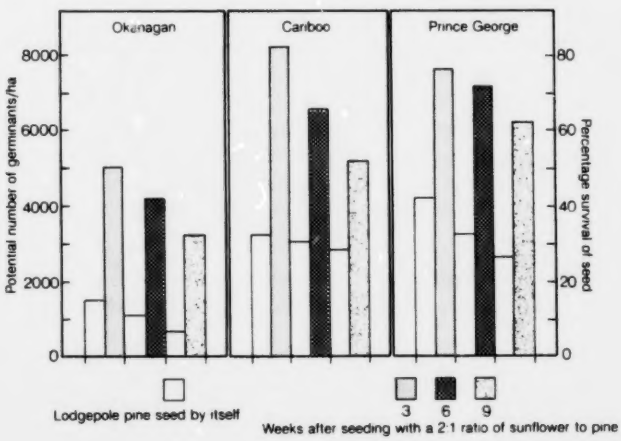
The success of different ratios (by number of seed) of Douglas-fir seed to sunflower seed (and oats in 5:2:1 ratio) at 2, 4, and 6 weeks after seeding. The open bars show survival of Douglas-fir seed by itself; the closed bars show survival of Douglas-fir seed when it is seeded with alternative foods. The potential number of germinants per hectare is shown for a seeding density of 0.11 kg (12 500 seeds) Douglas-fir seed per hectare, and assumes 80% germination.

Experimental seeding trials were conducted on two coastal clearcut blocks (Douglas-fir) and three interior cut blocks (lodgepole pine). Known densities of seed (Douglas-fir, lodgepole pine, sunflower, and oat kernels) were placed in 25 sampling quadrats randomly chosen on each of the established experimental grids. Ratios in seed numbers, sunflower seed to Douglas-fir seed, were 7:1, 5:1, 3:1, and 0:1 (control); and for a combination, sunflower seeds to oat kernels to Douglas-fir, 5:2:1. The ratio of sunflower seed to lodgepole pine seed was 2:1 and 0:1 (control).

Seed survival sampling of Douglas-fir was conducted at 2-week intervals for 6 weeks, and of lodgepole pine, at 3-week intervals for 9 weeks. As the figures below show, there was a marked improvement in conifer seed survival produced by the 7:1 and 5:2:1 alternative food/seed ratios for Douglas-fir and the 2:1 ratio for lodgepole pine.

Reforestation programs that adopt direct seeding with alternative foods should be conducted during the late winter or early spring (after most of any winter snow cover is gone), in the year after an area is logged. Mechanical or chemical site preparation will be required before seeding on older, overgrown clearcut areas. The recommended mixtures of conifer seed and alternative foods are:

1. for Douglas-fir sites in the Coastal Western Hemlock and Coastal Douglas-fir biogeoclimatic zones: 0.11 kg (12 500) Douglas-fir, 46 kg sunflower, 5.5 kg whole oats; or 0.11 kg Douglas-fir and 64 kg sunflower per hectare.



The success of lodgepole pine seed mixed with sunflower seed (2:1 ratio sunflower to pine) at 3, 6, and 9 weeks after seeding at three study areas in the interior of British Columbia. The open bars show survival of lodgepole pine seed by itself; the closed bars show survival of lodgepole pine seed when it is mixed with sunflower seed. The potential number of germinants per hectare is shown for a seeding density of 0.04 kg (12 500 seeds) lodgepole pine seed per hectare, and assumes 80% germination.

2. for lodgepole pine sites: 0.04 kg (12 500) lodgepole pine with 18 kg sunflower per hectare.

Tom Sullivan

*Deer mouse (*Peromyscus maniculatus*).*

The recommended 12 500 conifer seeds in these mixtures represents the minimum number of tree seeds required by this technique to achieve successful stocking, and although the amount may be varied, the amounts of alternative foods should remain fixed to ensure adequate protection from rodent predation. To promote germination within a 2- to 4-week period after seeding, the conifer seed should be stratified for at least 3 weeks and may be treated with growth hormones as well.

Production Efficiency in Container Seed Orchards (EP 865)

The flowering response to induction treatments of potted and field-grown trees was compared in western hemlock and Engelmann spruce. (Results of earlier research with Engelmann spruce were reported in *Forest Research Review 1983-1984*.)

Trees were vegetative propagules of mature plus-trees, with different clones and ramets of different ages (hemlock) or similar ages (spruce), represented in the two orchard types. All trees were treated with spray applications of gibberellin $A_{4/7}$ ($GA_{4/7}$), calcium nitrate fertilizer, and moderate drought, appropriately timed for each species. Potted trees of hemlock received these treatments both outdoors and in an unheated plastic-covered house; spruce received the treatments both outdoors and in a 30°C/20°C heated house.

Without treatment, flowering by both species in both orchard types was poor. Treatment of western hemlock in the soil-based orchard increased the mean number of seed-cone buds initiated per ramet from less than five to nearly 320 and the proportion of clones that flowered from 27 to 100%. However, the younger (7-year-old) potted trees initiated 33% more seed-cone buds each, in response to treatment indoors, than did the older (12-year-old) field-grown trees. Outdoors, the potted trees were less responsive to treatment, although flowering in clones was again 100%.

Comparison of 1985 flowering responses for 7-year-old potted and 12-year-old field-grown western hemlock rooted cuttings at the MacMillan Bloedel Harmac Tree Improvement Centre, British Columbia

Flowering response	Potted seed orchard[a]			Soil-based seed orchard	
	Untreated	Treated			
	Outdoors	Outdoors	Indoors	Untreated	Treated
Female flowering					
Ramets (= clones) flowering (%)[b]	75	100	100	27	100
Females/tree (no. ± S.E.)	52 ± 22	257 ± 65	427 ± 63	3 ± 2	319 ± 131
Male flowering					
Ramets (= clones) flowering (%)	56	73	86	36	61
Mean pollen score[c]	1	1.6	2.2	1	1

[a] *All treated trees received calcium nitrate fertilizer in spring and 6 weekly foliar sprays of 200 mg L^{-1} $GA_{4/7}$, commencing at vegetative bud burst. Potted trees, additionally, were subjected to a simultaneous 6 weeks of moderate drought.*

[b] *One ramet per clone per treatment, with a different group of 22-23 parent-tree clones represented in each orchard.*

[c] *Pollen cone production scored: 0 = none, 1 = light, 2 = moderate, 3 = heavy.*

The difference in treatment response was even more dramatic for Engelmann spruce where the grafts in the two orchard types were of similar ages. Heat treatment by tenting significantly enhanced female flowering in the soil-based orchard, although still only 24% each of the ramets and clones produced seed-cone buds. In contrast, nearly 90% of the clones whose potted ramets received heat and $GA_{4/7}$ treatment indoors flowered, and their mean production of seed-cone buds was almost 4 times that of the similarly treated field-grown trees. Pollen production by both species in the young soil-based trees was sparse in relation to female flowering. The smaller potted trees, by contrast, produced pollen in abundance.

The results suggest that where potted trees are properly managed, profuse flowering should be possible to achieve biennially. However, retreatment of soil-based orchards may or may not be successful, depending on climatic conditions in the year of stimulation. Even the most effective treatments, including applications of $GA_{4/7}$ in conjunction with nitrogen fertilizer, girdling, and root-pruning, can be hampered by adverse site and climatic factors.

Indoor potted orchards offer another important advantage in that the developing cones and seeds can be protected from harsh climatic conditions. A comparison was made between cone and seed development traits for potted ramets of the same western hemlock clones, which had been induced to flower and were subsequently maintained either outdoors or in an unheated plastic-covered house. Not only did the trees outdoors initiate significantly fewer seed cones, but the proportion of those that survived was also significantly lower than those indoors—attributed to several severe freezes during winter and early spring. The cones that did survive outdoors contained fewer total (filled plus empty) seeds. In this comparison, unbagged female strobili on both groups of trees were supplementally pollinated at least three times (at maximum receptiveness) with the same pollen lot from potted ramets indoors. The filled seed percentage was still lower outdoors,

Cone and seed traits compared for potted western hemlock rooted cuttings induced and maintained outdoors or in an unheated greenhouse

Trait	Outdoor (X+S.E.)	Indoor (X+S.E.)
Cones initiated/tree (no.)	320 ± 23	633 ± 30
Surviving cones/tree (no.)	198 ± 13	529 ± 26
Cone efficiency (%)	62	84
Total seed/cone (no.)	27 ± 1	31 ± 1
Filled seed/cone (no.)	10 ± 1	14 ± 1
Seed efficiency (%)	37	45
100-filled seed wt. (mg)	200 ± 5	199 ± 5
28-day germination (%)	79 ± 5	82 ± 5

possibly because the cool, moist conditions that prevailed throughout the pollination period adversely affected pollen germination and subsequent fertilization of ovules.

For western hemlock and presumably most conifers, optimal conditions for cone and seed development are the same as those that favour vigorous vegetative growth: abundant water and nutrients, along with moderate temperatures. Thus, potted trees offer an advantage in that they may be managed separately for each initiation and development of reproduction structures and so ensure maximum production of high-quality seed—a practice not generally possible with soil-based orchards.

Steve Ross

Profuse cone production on a 5-year-old potted interior spruce graft.

The Ecosystem Classification Program: Mapping of Biogeoclimatic Units*

The first in a series of biogeoclimatic subzone/variant maps planned for each of the province's six forest regions was produced for the Vancouver Forest Region in 1984/85.

Mapping was carried out by a combination of ground and aerial surveys. Subzone and variant boundaries were mapped according to the occurrence of zonal ecosystems, identified by the presence of various tree, shrub, herb, moss, liverwort, and lichen species appearing in specific characteristic combinations on zonal sites. In unsurveyed areas and where zonal ecosystems did not occur, the boundaries of these biogeoclimatic units were extrapolated according to elevation.

The completed map, at a scale of 1:500 000, shows the six zones, divided into 23 map units comprising either single biogeoclimatic variants/subzones or various undifferentiated units. In addition, grids of elevational limits for each biogeoclimatic unit and a list of the zonal ecosystem associations for each biogeoclimatic subzone are shown.

With this map (including the elevational grids), and a check of the major species on an area's zonal ecosystems against those listed for the zonal ecosystem associations, the identification of biogeoclimatic units within any part of the Vancouver Forest Region is now possible. This map, as well as the existing and planned reports, is expected to have widespread application in all aspects of forest, range, wildlife, recreation, or watershed resource management in the region, and is already being used extensively in site diagnosis, tree species selection, and slashburning prescriptions.

(*No specific EP number. For further information contact D. Meidinger, Research Branch.)

Operational Pelleting of Seed (EP 909)

The operational sowing of pelleted seeds of western redcedar continued in 1984/85. Although some pellets failed to disintegrate when pelleting was initially implemented, this problem was overcome by increasing the frequency of watering. The system is now well received in the nurseries, and sowing requests for pelleted western redcedar increased to almost 5 million seedlings in 1985. Labour cost savings from sowing pelleted seeds are substantial, presently amounting to $160 000 annually.

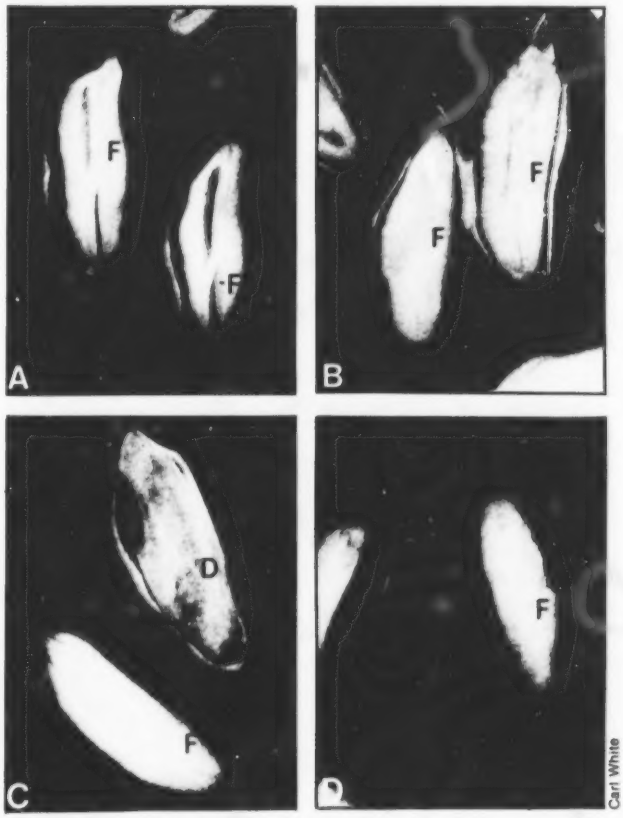
In addition, experiments were conducted on pelleted seed to test disintegration rates of various binder strengths. It was found that at a strength 25% of the original amount, pellets completely broke down in water within 20 seconds; at 50% strength, breakdown occurred in 1.5 minutes; and at 100% strength, breakdown took at least 10 minutes. Tests on the integrity of weaker pellets (25 and 50% strength) showed no evidence of disintegration during mechanical sowing.

While seeds for the 1985 season are being pelleted with the 100% binder formulation, tests on seeds pelleted with other binder concentration are continuing to determine binder specifications for 1986.

Stratification to Improve Seed Performance
(EP 848)

Although the characteristically slow and unpredictable germination of *Abies amabilis* seed has been substantially improved by better collection and handling techniques, without seed treatment dormancy remains an impediment to seedling production efforts. Stratification, the moist storage of seeds at 2°C for 3 or more weeks, is the most common technique now used to break dormancy. A modification of this method is the stratification-redry technique which, by controlling the seed moisture level during the chilling period, has been found to improve germination significantly. However, because many variables affect the response of tree seeds to chilling, stratification cannot be considered in isolation from the many other factors interacting with the crucial events that occur during the chilling period.

In 1984/85, investigations were initiated into the effect of various factors on the germination of stratified *A. amabilis* seeds sown in the laboratory and in the nursery. Seed vigour, chilling method, seed source, collection year, and germination temperature were all found to interact with stratification. The experiments found that low-vigour seeds were adversely affected by stratification, tending to deteriorate during storage at 2°C. The stratification-redry method generally increased germination relative to other methods tested, but the response was influenced by seed source and year of collection. Regardless of method, stratified *A. amabilis* seeds germinated more slowly but completely under cold (15°C/10°C) than under warm (30°C/20°C) conditions.



Deterioration of seeds during extended stratification:
A - Unimbibed seeds (moisture content <10%)
B - Seeds imbibed for 24 hours (moisture content 40%)
C - Seeds stratifiedfor 4 weeks
D - Seeds stratified for 8 weeks.
X-rays of all imbibed seeds were taken after the seeds were first dryed for 15 minutes to improve resolution. F = filled seed; D = deteriorated seed.

Seed Dormancy in Three Pinus *Species*
(EP 848)

The expression of seed dormancy, though genetically controlled, is strongly influenced by environmental factors. In fact, through variations in environment, plant populations become physiologically specialized along the environmental gradient.

In a study to investigate the type and degree of dormancy restricting seed germination in members of the same genus, and to determine if control of dormancy could be related to a species' habitat of origin, several seed sources of whitebark pine, lodgepole pine, and western white pine were given various treatments. Stratification (moist chilling at 2°C) and partial removal of the seedcoat was used to examine the occurrence of physiological and mechanical dormancy, whereas X-rays were used to assess development of embryo and gametophyte tissue. Where incomplete development was suspected, a combination of warm (20°C) and cold (2°C) stratification was also used to enhance development and overcome dormancy.

Results of the study showed that physiological dormancy, measured as the degree of response to various stratification periods, can be related to seed habitat of origin. In whitebark pine and western white pine dormancy was greatest, and in lodgepole pine it was least. Seedcoats significantly restrained radicle protrusion in whitebark pine and western white pine, but only slightly affected germination of lodgepole pine. Germination of whitebark pine is also commonly restricted by seed immaturity because of the short growing seasons found in subalpine regions. Presumably, as life strategies vary with changes in local environments, so dormancy control mechanisms would differ.

Whitebark pine is a species able to survive in marginal subalpine habitats with short growing seasons. Although seeds often do not mature on the tree, animals cache them in the soil where they continue to ripen during long storage under the snow. The large variability in seed development and dormancy ensures that only a few individuals germinate at a time, increasing the chances of survival of the species in a harsh environment.

A pioneer species in the initial seral stage of ecosystems, lodgepole pine seeds exhibited low dormancy. Because habitats become less favourable for the species once the canopy starts to close, germination tends to occur quickly. Western white pine on the other hand, unlike the previous two species, exists in a comparatively stable environment, where rapid or prolonged germination is unnecessary. Seed dormancy in this species appears to be governed by factors other than environmental.

Further research to understand the control of dormancy in coniferous seeds is recommended.

THE BRITISH COLUMBIA GENE ARCHIVES

The gene archives are a vital component of the coastal and interior tree improvement programs in British Columbia. Consisting mainly of clonebanks that contain grafts or rooted cuttings from selected parent trees (there are some plantations of seedling origin), the archives conserve valuable genetic material from all important coastal and interior forest tree species. This material provides scions for seed orchard development, and is available for tree breeding and other research purposes where knowledge or control of genetic variability is advantageous.

*Coastal Gene Archive Development**

Gene archives for the coastal region of British Columbia are located at the Cowichan Lake Research Station on southern Vancouver Island. The products of more than 30 years of selection and breeding by the Ministry of Forests are held here. Clonebanks form the major component of the coastal gene archives, and now include eight species and 3212 clones. A large Douglas-fir provenance arboretum, containing 148 population samples from throughout the species' range, and material from Douglas-fir inbreeding experiments (including two lines inbred to the S_3 generation) are among the largest non-clonal collections in the coastal archives. Other major plantations include a Douglas-fir early selection (farm-field) test, a yellow-cedar hedging orchard for the mass production of cuttings, a Douglas-fir interracial cross progeny test, a lodgepole pine provenance collection, and species aboreta for the genera *Pseudotsuga* and *Tsuga*.

(*No specific EP number. For further information contact J. Woods, Research Branch.)

Number of clones of selected parent trees established in clonebanks in British Columbia

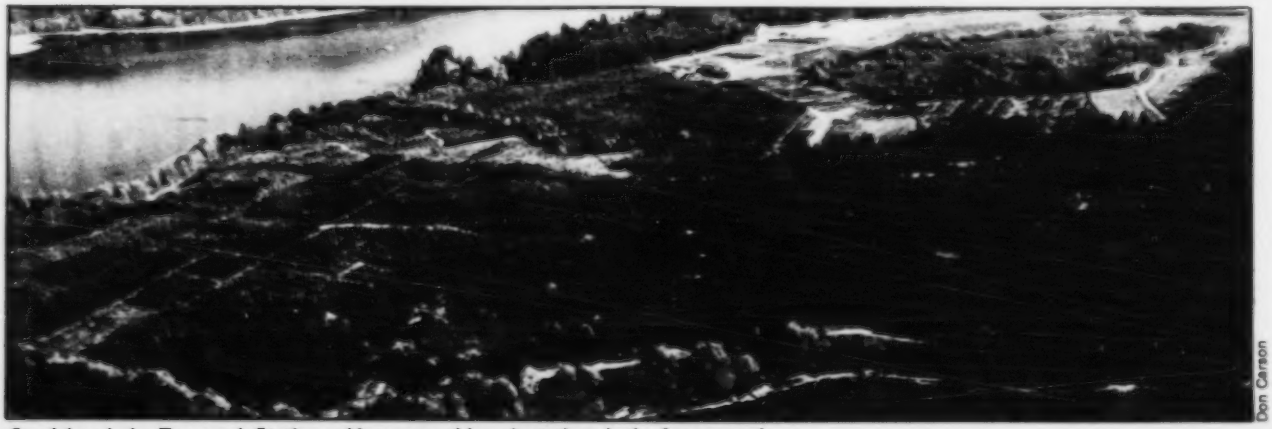
Species	Established clones	Location[a]
Douglas-fir (coast)	955	1
Douglas-fir (interior)	705	1, 2
Western hemlock	896	1
Interior spruce	1005	1, 2, 3
Lodgepole pine	792	3
Sitka spruce	138	1
Western redcedar	222	1
Yellow-cedar	335	1
Amabilis fir	186	1
Grand fir	49	1

[a] *1 = Cowichan Lake Research Station, Vancouver Island.*
2 = Barnes Creek Arboretum, located 80 km north of Vernon, B.C.
3 = Red Rock Forest Reserve, Prince George, B.C.

*Interior Gene Archive Development**

Gene archives are being established in the interior of British Columbia in conjunction with breeding programs for interior spruce, lodgepole pine, and Douglas-fir. Spruce and lodgepole pine clonebanks have been expanded recently at the Red Rock Forest Reserve near Prince George, and Douglas-fir clone-bank establishment continues at the Barnes Creek arboretum, north of Vernon. In addition, breeding arboreta for each species have been developed by the respective breeders at the Kalamalka Research Station at Vernon.

(*No specific EP number. For further information contact J. Woods, Research Branch.)



Don Carson

Cowichan Lake Research Station, with gene archive plantations in the foreground.

VEGETATIVE PROPAGATION RESEARCH*

The development and improvement of techniques for efficient vegetative propagation are providing new tools for intensive forest management. For species whose seed supplies are limited, vegetative propagation can augment the available and desirable seed sources to meet reforestation needs. The approach is already being applied to yellow-cedar, with 150 000 cuttings now propagated annually for reforestation projects. Since 1975, 50% of all yellow-cedar propagules have taken this form.

Research is continuing, with efforts to expand the technique's application to other species. Although most seed requirements will eventually be met by seed orchards, improved planting stock can be made available sooner through vegetative multiplication of early, limited production. For species with established breeding programs, such as interior spruce and coastal Douglas-fir, as progeny test information accumulates, specific superior combinations can be multiplied and used to maximize genetic gains in current reforestation practice.

The yellow-cedar program illustrates how this research can be integrated with production. Initially, natural seedlings from suitable areas were collected and brought to Cowichan Lake Research Station for study and seed and propagule production. However, reduced rooting success because of maturation later led to the establishment of a hedge orchard, which was annually pruned to maintain the juvenile condition. To complement the yellow-cedar production program and develop techniques for interior spruce and coastal Douglas-fir, research is under way to examine three methods of multiplication for providing large numbers of vegetative propagules from single seeds in a short time while acceptable maturation levels are maintained. These methods include:

•*accelerated growth*, through which seedlings will be produced under extended photoperiods, optimum temperatures, and optimum nutrient regimes. With this approach, it may be possible to achieve a multiplication factor of 10-100 in the first growing season, depending on the species.

•*serial propagation*, with which cuttings from other recently rooted cuttings will be propagated repeatedly. Aggressive serial propagation over a 4-year period can result in the production of hundreds of thousands of stecklings (plantable rooted cuttings) from one seed and a slowing of maturation rate.

•*hedge orchards*, which will provide cutting-donors from families or clones and, by being sheared regularly, will produce a large number of shoots while possibly maintaining juvenility.

These approaches are now being applied to interior spruce and coastal Douglas-fir, aimed at developing techniques for the large-scale production of rooted cuttings from juvenile cutting-donors and for testing the performance of the rooted cutting

Work is already progressing in four types of tests which will generate different types of information:

1. Seedling:steckling comparisons, which involve planting seedlings and rooted cuttings from the same genetic families, will provide essential information on how stecklings and seedlings perform in the short and long terms.

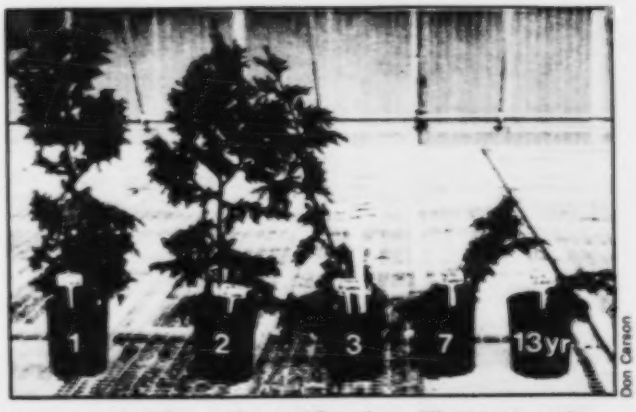
2. The different techniques for obtaining large numbers of cuttings from a single seed (described above) will be monitored with respect to production, rooting (amount and quality), and steckling performance (growth and form) in the field.

3. Clonal testing to obtain genetic information and rank clones for selection will help determine if there is any exploitable clonal variance for commercial traits.

4. Rooting and nursery cultural trials will ultimately guide the production of optimal rooting percentages and high quality stecklings.

The yellow-cedar program is now providing material for reforestation. New research projects are expected to demonstrate the wider potential of vegetative propagation for other species. When the techniques have been perfected it will be possible to: 1) augment operational planting stock with genetically improved families before seed from comparable families in seed orchards are available; 2) capture additional genetic gains from specific crosses that are showing favourable performance in existing field tests; and 3) provide genetically identical replicates for more efficient research experiments.

(*No specific EP number. For further information contact J. Russell, Research Branch.)



Two-year-old yellow-cedar stecklings from different age cutting donors.

Experimental Design Protocols for Forest Vegetation Management Research **(EP 970)**

Faced with the growing importance of forest vegetation control and the need for research on a wide range of vegetation management systems and techniques, the Research Branch initiated the preparation of guidelines to ensure the quality and cost effectiveness of the information collected. Known as experimental design protocols, and adopting many of the features of the Oregon State University CRAFTS protocols, these guidelines define minimum standards for vegetation management trials at two levels.

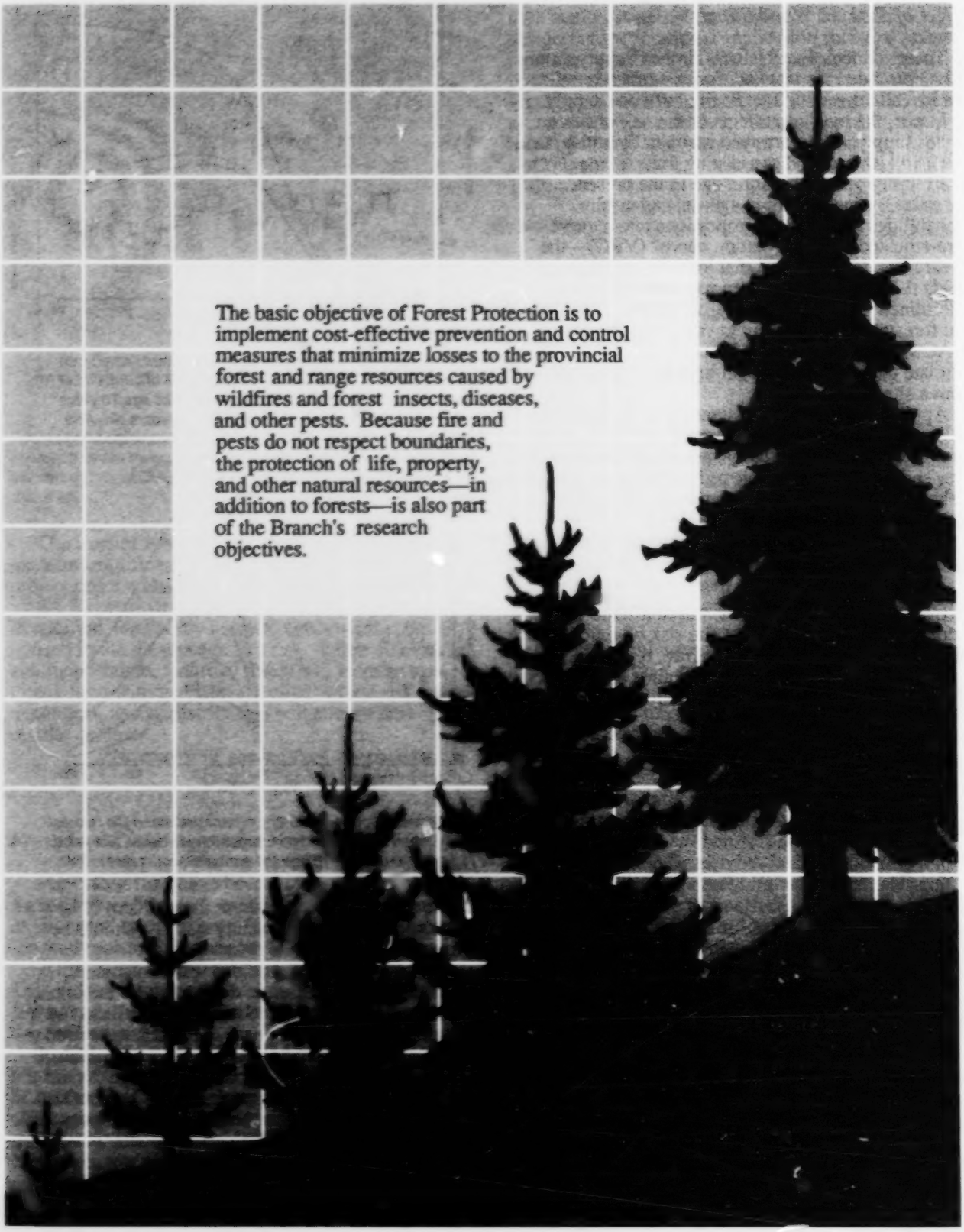
The Level A protocol for screening trials provides standards for the least intensive level of experimentation. There are two types of screening trials for which it should be used: operational treatments (for site preparation and standard establishment strategies 1-3 years after a plantation is established); and experimental treatments (in cases where the use of large treatment plots is unwarranted). The type of tests for which screening trials—and the Level A methodology—would be used include: monitoring short-term crop tree response and treatment efficacy on a small number of weed species; evaluating an array of vegetation management treatments for further testing; and verifying, under localized climatic conditions, those treatments recommended in the US Pacific Northwest.

The Level B protocol provides standards for intensive study of new treatments which, because they require greater investments of time and capital, only proceed if the results of preliminary screening trials show a high probability of success. Level B methodologies are prescribed for three types of trials that monitor short- and long-term responses of crop trees and target species, and shifts in composition of the vegetation community:

1. site preparation trials, to test treatments (mechanical brush clearing, prescribed fire, herbicides) for managing vegetative competition before the planting operation. Experimental procedures recommended for these trials are described for two types of investigation: low vegetation control treatments (applied to sites occupied by herbs, forbs, grasses, ferns and shrubs, and trees <3 m); and high vegetation control treatments (applied to sites occupied by weed hardwood or softwood trees >3 m).
2. stand establishment trials, to test vegetation control treatments prescribed from one growing season to several years after planting.
3. stand release trials, to test treatments for reducing or eliminating vegetative competition in established stands.

Both the Level A and Level B trials have common design and assessment conventions, and the data collected by both methodologies is compatible and complementary. These protocol guidelines are a first approximation.

PROTECTION RESEARCH



The basic objective of Forest Protection is to implement cost-effective prevention and control measures that minimize losses to the provincial forest and range resources caused by wildfires and forest insects, diseases, and other pests. Because fire and pests do not respect boundaries, the protection of life, property, and other natural resources—in addition to forests—is also part of the Branch's research objectives.

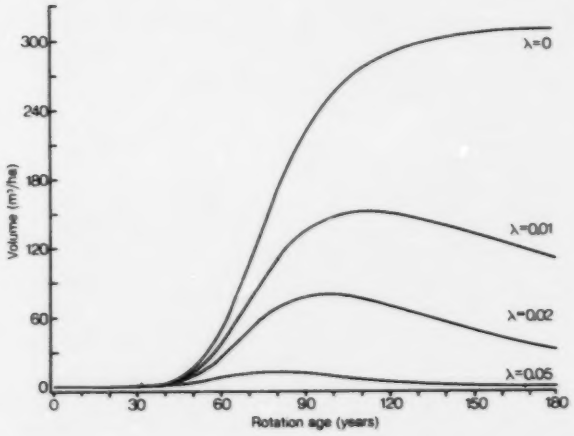
*Effect of Fire on Wood Supply**

The province's Fort Nelson Timber Supply Area (TSA) provided the test data for two related studies that investigated the effect of fire on wood supply.

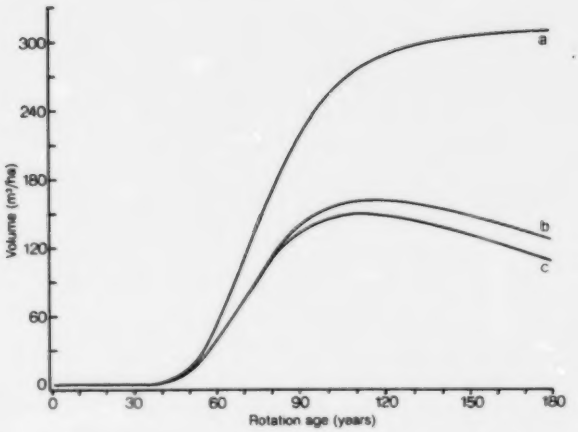
In one, the long-run effects of the risk of fire on timber supply were portrayed graphically at the stand level, and were aimed at assisting forest managers in determining optimal rotation age in the presence of fire risk. By incorporating age-dependent fire probabilities and salvage proportions into a curve—a "fire-adjusted volume-rotation curve" (VRC)—the researchers demonstrated that long-run average yields (LRAY's) for a chosen rotation age can be determined by the traditional graphical techniques that foresters usually apply to volume-age curves (VAC's). The curves may therefore be used to estimate the impact of fire on long-run average yield from a site.

Applied to white spruce stand data from the Fort Nelson TSA, the technique showed that even modest rates of fire can substantially shorten optimal rotation ages and result in very large reductions in long-run yield. As to the effects of fire risk on land expectation values, the study also showed that even low rates of fire can dissipate the potential land rent from a managed site.

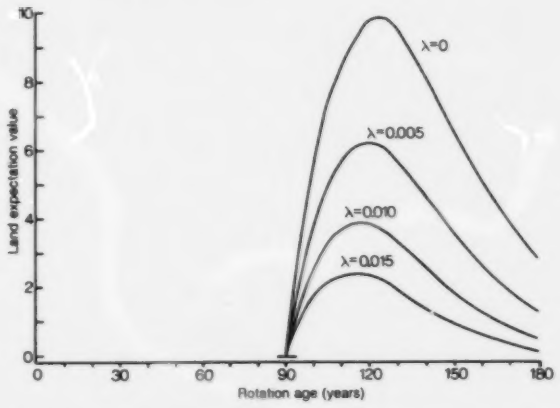
Unlike the first study, which used a stand-level model to assess the effects of fire risk on output from a single site (and does not, therefore, represent situations where forest-wide constraints are imposed across many stands), the second study adopted a whole-forest model to address the problem of how a forest unit—made up of many stands—should be managed in view of fire risks.



The fire-adjusted VRC corresponding to annual fire rates (λ) 0 (the VAC), 0.01, 0.02, and 0.05.



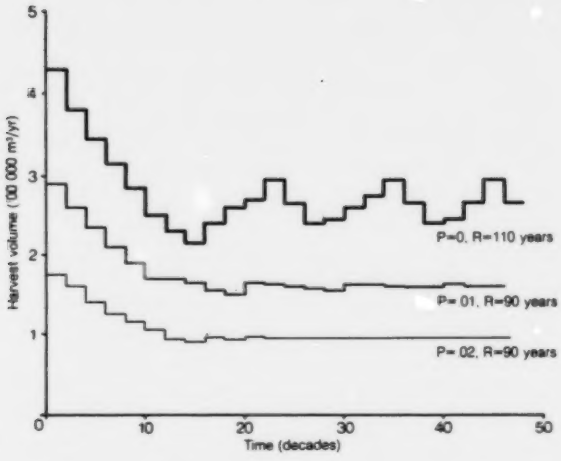
Fire-adjusted VRC corresponding to a constant hazard with λ = 0.01 and the possibility of partial salvage of burnt timber (b). The expected salvage proportion is 0 for trees age 70 years or less and 25% for trees of greater than 70 years old. Also shown are the no-fire VRC (a) and the VRC corresponding to λ = 0.01 with no salvage (c).



Land expectation value for an unmanaged stand (no reforestation) when there is a 40-year regeneration delay. Fire rates (λ) are 0, 0.005, 0.015 and the annual discount rate is 3%.

A set of dynamic equations was constructed, describing the evolution of a forest under the impact of harvesting and losses to random fire. Based on a deterministic approach, these equations were used to formulate an optimal harvest scheduling problem, which was solved by linear programming. Again using the white spruce data of the Fort Nelson TSA as an example, the researchers showed that even modest rates of fire can dramatically lower harvest levels, and that existing harvest scheduling models may be over-estimating projected forest outputs. With one particular growth curve, for example, a 1%

per annum rate of loss through fire produced a 40% loss in maximum sustainable yield. Results further showed that the deterministic approach offered a reasonable approximation of the real stochastic fire problem.



Optimal harvest level solutions for the deterministic approach for fire destruction scenarios corresponding to per annum probabilities of 0, 0.01, and 0.02. Time discount rate is 0%.

The implications of such results for forest management are significant. For one, current timber supply projections tend to be too high if they are based on whole-forest models that ignore catastrophic losses. In addition, the "normal forest" concept must be revised in the presence of fire risk: where fire risk is age-independent, a normal forest will have an age distribution with geometric decline; where risk is age-dependent, its age distribution will show a less regular decline.

(*No specific EP number. For further information contact D. Errico, Research Branch.)

*Prescribed Fire Assessment Handbook**

Prescribed fires have been a part of forest management for over 70 years, yet data on the burns, such as fire weather conditions, fuel loading, soil, vegetation, and moisture and nutrient characteristics, have been measured inconsistently or not recorded at all. This lack of information has made it difficult for foresters to monitor prescribed fires and determine their effectiveness.

In response to the problem, the Ministry prepared the *Field Handbook for Prescribed Fire Assessments in British Columbia*, setting out a systematic, objective procedure for documenting prescribed fire treatments. The handbook is the first step in the Ministry's goal to establish a data base for a computerized prescribed fire management information system. Such a system, it is anticipated, will allow detailed analysis of prescribed fire data and improve future fire prescriptions.

To encourage its acceptance and use—and hence the successful establishment of the planned information system—the handbook has been designed for operational application (pre-fire assessments are estimated to take two people 1 day, and post-fire assessments to take two people a half day). Procedures were field tested in 1985 and 1986 on prescribed burns conducted around the province, and it is hoped they will be used to document an additional 150 prescribed burns between 1987 and 1989.

(*No specific EP number. For further information contact J. Parminter, Protection Branch.)

FOREST PEST STUDIES

*Controlling Douglas-fir Tussock Moth with NPV**

For years, Douglas-fir stands in the interior dry-belt of British Columbia have suffered from periodic outbreaks of the Douglas-fir tussock moth (*Orgyia pseudotsuga* (McDunnough)). Infestations by this forest pest have attacked thousands of hectares of productive forest annually. Tree damage is caused through larval feeding, and the extent of tree mortality, top-kill, growth reduction, and foliage recovery is directly related to the extent of defoliation that results.

Of the natural agents that control tussock moth—including parasites, predators, pathogens, and starvation—the nuclear polyhedrosis virus (NPV) is regarded as the most important in inducing the pest's population decline. Its natural build-up within a population is generally too slow to prevent top-kill dieback or the loss of tree growth; but in concentration, applied at early stages of infestation, NPV can greatly limit damage. It offers a good biological control alternative to chemical insecticides.

The Protection Branch has been conducting a number of studies to determine what methods and dosages of NPV are most effective for operational application. In one, the efficacy of reducing NPV concentrations (and so the cost of treatments) was tested with aerial spraying trial in Cache Creek, B.C. It was found that a concentration of 8.3×10^{10} PIB (polyhedral inclusion bodies)/ha was as effective in controlling Douglas-fir tussock moth as the recommended 25×10^{10} PIB/ha. As well, it was shown that NPV formulated in molasses had a better spray deposit than NPV formulated in oil.

In a second study, ground treatment with NPV and the spread of the agent to untreated areas was examined. Trials, again in Cache Creek, were carried out to investigate the effectiveness of making spot applications of NPV with ground spraying

equipment, and to assess the extent of NPV dispersal within an infested area from a spot application point. The virus was applied by commercial ground sprayer to a small stand of Douglas-fir in dosages of 3.6 x 10^9 PIB per litre mix per tree. Larval population data showed that larval survival in the inoculum centre decreased from a pre-spray ratio of 1.0 to 0.24 by the 2nd week after spraying, and that by the 7th week it reached 0.01. Results of NPV smear analysis indicated that the NPV had a spread from the inoculum centre of 15 m to south and west and 25-50 m to the north—with the latter probably caused by the predominant wind pattern at the study site.

In anticipation of future outbreaks of the infestation (likely the early 1990's), the Ministry is purchasing a 6000-ha equivalent of NPV from the U.S. Forest Service's production facility.

(*No specific EP number. For further information contact J. Henigman, Protection Branch.)

*Gypsy Moth Strategic Plan for British Columbia**

The B.C. Plant Protection Advisory Council has sponsored a novel initiative to develop a strategic plan to deal with this potentially major pest. The plan includes identification of roles and responsibilities for key agencies of federal and provincial government to consider for three sequential scenarios:

Phase I	Emergency Eradication Programs (federal responsibility)
Phase II	Expanding Control Operations (federal/provincial responsibility)
Phase III	Resident New Pest Control Operations (provincial responsibility)

Because gypsy moth may infest a wide range of host plants in urban, agricultural, and forest settings, research priorities specifically for British Columbia conditions will be recognized. Thus, research establishments and academic institutions here will have the benefit of operational interagency discussion and recommendations well in advance of the unexpected dilemma situation. Protection Branch staff, via membership in the Council, are participating in this assignment, which is to be completed early in 1986.

(*No specific EP number. For further information contact R. DeBoo, Protection Branch.)

*Mountain Pine Beetle Management**

The success of trials using bark beetle aggregating pheromones was reported in 1983/84. Although these semio-chemicals do not control beetle populations on their own, they do enhance the effectiveness of direct control techniques by restricting dispersal. In British Columbia, the two direct control techniques most often used in removing, or at least reducing, the size of the beetle population are sanitation harvesting (in which pheromones are used as bait to contain beetle populations in infested cutblocks) and single tree treatments (in which pheromones are used as bait in small infestation patterns).

A number of surveys of the effects of baiting indicate that the baiting program is having success. For example, in a trial of containment baiting conducted in the Nelson Forest Region, small blocks were baited in a 50-m block and a surrounding 150-m zone were completely surveyed to evaluate the ratios of green trees attacked to brood trees attacked. Preliminary results show that baited areas had more than 5 times the concentration of new attacks than adjacent untreated areas.

The technique of containment baiting to sanitize lightly infested areas has become increasingly accepted in British Columbia, as has the use of pheromones in single trees. The purchasing and application of pheromones are carried out by both the Forest Service and industry (either through credits to stumpage allowance or as a direct cost of doing business). The Forest Service alone purchased over 34 000 baits in 1985, to be used for containment and mop-up of single tree treatment sites—up from the 100 it purchased in 1982 (mainly for demonstration trials), 2000 in 1983, and 7000 in 1984.

Sanitation cutting, incorporating the use of aggregating pheromones, is planned for all six of the province's forest regions.

A number of guidelines are offered to enhance the effectiveness of pheromone use in improving direct control programs:

- The timing and selection of trees to bait are important. Baits must be placed in the field before any possible beetle flight to prevent natural attractant centres from establishing first, but not too early, or some of the pheromone components may dissipate before beetle emergence.
- The largest, most susceptible-looking trees should be selected for baiting, as beetles normally have a preference for such trees.
- Pheromones should only be used in conjunction with other practices. Used on their own, they might increase the problem rather than eliminate or reduce it.

(*No specific EP number. For further information contact P. Hall, Protection Branch.)

*Pesticide Handbook**

In 1985/86 the Ministry, co-operatively with the Council of Forest Industries, published the seven volume *Forest Pesticide Handbook of British Columbia*. Containing detailed information and operational guidelines for foresters and other pesticide users in the province, it describes:

- the procedures and safety practices required in a forest project involving pesticide use.
- the currently registered pesticides of interest to foresters, and includes toxicological information, cautions, disposal, symptoms of poisoning, and first aid.
- aerial and ground pesticide application techniques.
- pesticide application equipment and its use.
- administrative aspects of forest pesticide use, including information on pesticide registration, the forest pesticide applicators certificate course, permit appeal procedures, and the policy positions of the Ministry of Forests and the Council of Forest Industries.
- pesticide labels.
- legislation affecting pesticide use.

The handbook represents the first comprehensive reference of pesticide technology, application, and legislation related to forestry in British Columbia.

(*No specific EP number. For further information contact J. Henigman, Protection Branch.)

*Pest Management Information System**

The lack of reliable information on forest pests and their impact, and the absence of an acceptable standardized provincial system to make such information available to forestry personnel, prompted the Protection Branch to establish a Task Force to address the problem. The Task Force set out to identify an effective data collection, storage, and retrieval system for pest information to aid foresters in planning and managing the forest resource. The ideal system, it was noted, would provide pest-related information for planning (calculating yields and annual allowable cuts; optimizing harvesting, silviculture, protection, and other programs to meet the objectives for managed units) and operations (scheduling timber harvesting operations; determining appropriate regeneration prescriptions; evaluating and implementing preventative and control measures).

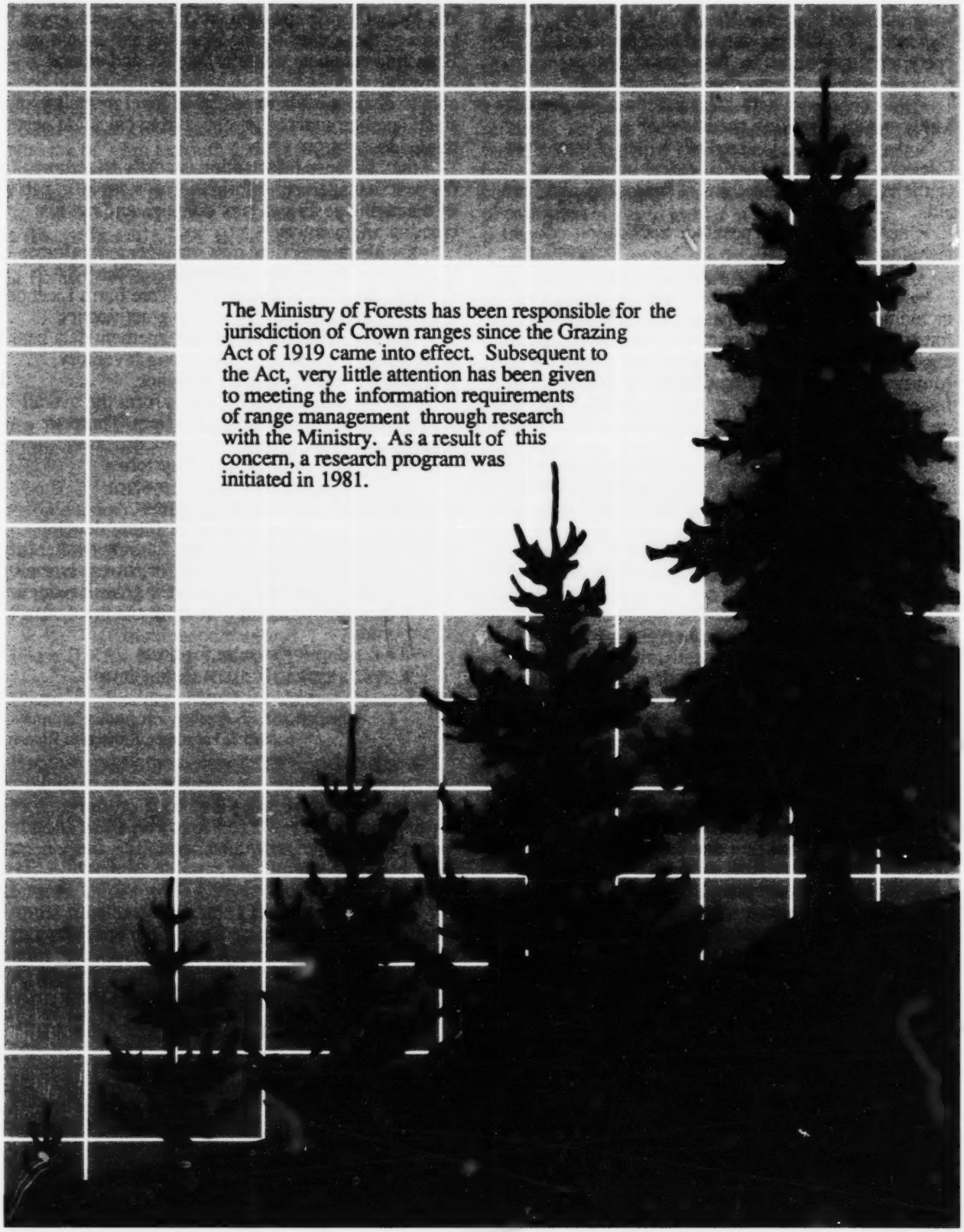
Among the Task Force's recommendations were the following:

- that the implementation of Inventory Branch's current service and support applications be rapidly accelerated.
- that, basic to its success, the appropriate pest management information system be operationally linked to the existing Forest Inventory System and the History Record System at the polygon mapping unit level.
- that the appropriate pest management information system be capable of using the same standards and format for determining actual or potential pest losses as those used by the Planning and Inventory Branch to calculate volumes, yields, and annual allowable cuts. In particular, the system should be able to distinguish between stand level mortality and stand level growth reductions, and to calculate pest-related losses from each.
- that, because information is costly to acquire, the pest management information system be capable of managing pests and their damage, and not just creating an inventory.
- that the appropriate pest management information system be capable of operating at the TSA (Timber Supply Area) and TFL (Tree Farm Licence) levels, and be structured to serve practitioners.
- that the enhanced forest management data base be developed co-operatively among Inventory, Silviculture, and Protection branches.
- that eventually eight systems form the overall pest management information system. Three are recommended for immediate development—
  - a pest occurrence mapping system
  - a pest management tracking system
  - a pesticide use recording system

  —and five are recommended for future development, according to priorities and funding availability:
  - a damage appraisal system for current mortality
  - a damage appraisal system for growth reduction
  - a damage appraisal system for the prediction of mortality
  - a hazard rating system for pests
  - a values system for pest management.

(*No specific EP number. For further information contact J. Parminter, Protection Branch.)

RANGE RESEARCH



The Ministry of Forests has been responsible for the jurisdiction of Crown ranges since the Grazing Act of 1919 came into effect. Subsequent to the Act, very little attention has been given to meeting the information requirements of range management through research with the Ministry. As a result of this concern, a research program was initiated in 1981.

*Forage Conditioning**

In recent years, the potential for resource conflict has been growing over the allocation of forage between elk and cattle on critical low-elevation ranges in southwestern British Columbia. As a result, forage conditioning has become an important range management technique, which aims at improving forage quality for wintering elk by controlling the season and intensity of cattle grazing. Although it forms the basis of many grazing schedules now applied in the East Kootenay region, the theoretical concept of forage conditioning has not been quantitatively evaluated, and many fundamental relationships between grazing and plant physiology remain poorly explained.

To address this problem, a literature review of the response by bluebunch wheatgrass and rough fescue to defoliation and abiotic factors was conducted. It revealed both evidence to support forage conditioning and evidence to disclaim it. Among that found to favour the practice were the following observations:

- Except for nonstructural carbohydrates, the nutrient content of regrowth is higher than the nutrient content of foliage from undefoliated plants.
- The rate at which nitrogen is leached from the foliage is independent of its concentration there, and therefore the enhanced N content of regrowth should not be negated by a more rapid nutrient loss caused by leaching.
- The defoliation responses of bluebunch wheatgrass and rough fescue can range from extremely positive to extremely negative, depending on the season and method of herbage removal.

Observations found to be contrary to forage conditioning theory indicated: 1) that carbohydrates may move from the foliage to the underground biomass during the curing phase; and 2) that environmental stress has little effect on the translocation process, so that even if translocation is interrupted by heat and drought, nutrient drain could well occur in the fall when physiological processes resume following summer dormancy.

Based on this review, a word model was designed to place the concept of forage conditioning within the context of a grazing system. It summarizes the relationships among grazing, climate, and physiographic factors and their effects on nonstructural carbohydrates, herbage production, and foliar nutrients. The word model offers a valuable step toward the development of a computer simulation model that could provide additional insights to this multidimensional, dynamic grazing system.

(*No specific EP number. For further information contact B. Wikeem, Research Branch.)

*Knapweed Containment and Control Program**

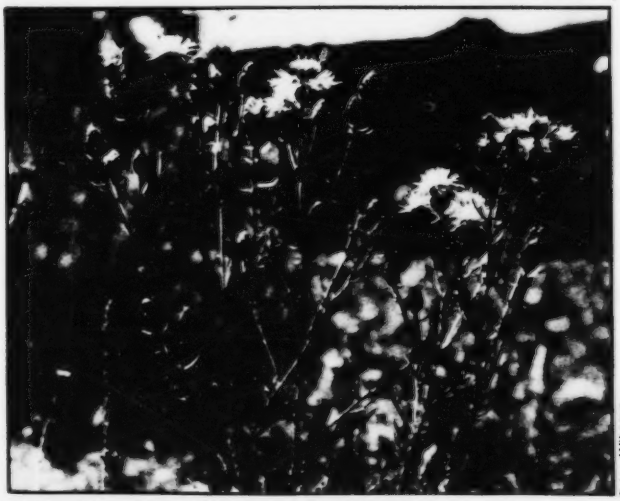
Since the introduction of several species of knapweed to North America from Europe at the turn of the century, the weeds have spread throughout large areas of semi-arid rangeland in the southern interior of British Columbia. With the potential invasion of these plants to all of the 1.1 million ha of grassland range in the province, as well as to areas of fringe and disturbed forest sites, efforts to control knapweed have been increasing.

A spray containment program has successfully retarded the spread of the weeds, but represents only a short-term solution until biological control agents can be found. Four of those are now established in British Columbia, including the two *Urophora* flies, *Metzneria*, and *Sphenoptera*. (*Agapeta* and *Pelochrista*, released in 1983, failed to establish and are currently being reared at Agriculture Canada research stations in Kamloops, B.C., and Regina, Sask., for release in 1986.)

The knapweed control program now under way involves the B.C. Ministry of Forests and Ministry of Agriculture and Food, Agriculture Canada, the University of British Columbia, and the Commonwealth Institute of Biological Control. It includes the collecting, screening, rearing release, and distribution of bio-control agents. Additional studies are focussing on the status of British Columbia's monitoring systems, to evaluate the success of operational chemical and biological control programs; the development of a sampling strategy to determine the impact of bio-control agents on knapweed seed production; the feasibility of using remotely sensed spectral reflectance data to monitor knapweed populations; and competitive interactions between knapweed and native plant species.

Research results are expected within the next few years.

(*No specific EP number. For further information contact B. Wikeem, Research Branch.)



Brian Wikeem

*Spotted knapweed (*Centaurea maculoas *Lam.)*

*Application of Sampling with Partial Replacement to Range Inventory**

One objective of the range inventory carried out by Range Management Branch is to estimate the monthly and annual total oven-dry production of herbaceous forage. Point estimates of forage production at given time intervals are used to define a yield curve, and then monthly and annual forage production are obtained numerically from the curve. The method of sampling used to generate the point estimates of oven-dry forage is cluster sampling with subsampling and double (two-phase) sampling.

In 1984/85, a project was undertaken by Research Branch to improve on this sampling method by incorporating sampling with partial replacement into the sampling design. Point and interval estimates of forage oven-dry weight per unit area were outlined, and questions relating to sample size were resolved. The design is now being applied in field trials, and preliminary results suggest that the sampling with partial replacement model will be a cost-effective means of collecting reliable seasonal and annual forage production data.

(*No specific EP number. For further information contact S. Omule, Research Branch.)

LIST OF ACTIVE EXPERIMENTAL PROJECTS

E.P. 502
Planting trials in the Prince Rupert Forest Region
J. Pollack

E.P. 511
Crop-tree thinning of western larch: Perry Creek, East Kootenay
C.F. Thompson

E.P. 513
Racial crosses with Douglas-fir
J.C. Heaman

E.P. 517
Experimental thinning and pruning of Ponderosa pine

E.P. 534
Spacing trial of Douglas-fir, 16 Creek, Vancouver Island
S.A.Y. Omule

E.P. 549
White spruce espacement trial, Anzac and Buckhorn Lake
L.J. Herring

E.P. 554
Correlated Curve trend study on Coastal Douglas-fir
S.A.Y. Omule

E.P. 570
Espacement trial of Sitka spruce, Terrace
J. Pollack

E.P. 571
Tree species and espacement trial, west coast Vancouver Island
S.A.Y. Omule

E.P. 586
.01 Comparison of four age-classes of Douglas-fir planting stock 21 years after planting
G. Krumlik

E.P. 589
Survival and initial growth of morphologically defined classes of Douglas-fir planting stock on high site lands subject to dense cover
F.T. Pendl

E.P. 599
Coastal Douglas-fir provenance study
C.C. Ying

E.P. 607
Effects of initial spacing of the growth and development of Ponderosa pine
C.F. Thompson

E.P. 611
Trial of species and provenances: Jennis Bay
C.C. Ying

E.P. 618
Cone crop periodicity in spruce, Nelson Forest Region
C.F. Thompson

E.P. 626
Engelmann spruce planting trials, 1964
C.F. Thompson

E.P. 630
Effects of juvenile spacing on individual tree growth in overstocked stands of lodgepole pine, Sheraton
J. Pollack

E.P. 640
Requirements of conifer seedlings for mineral nutrients
R. van den Driessche

E.P. 643
Prediction of nutrient status in Douglas-fir by foliar analysis
R. van den Driessche

E.P. 646
Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince George plantations
G.K. Kiss

E.P. 648
Grafting in Douglas-fir
I. Karlsson

E.P. 652
Dormancy and frost hardiness
R. van den Driessche

E.P. 657
Variation in lodgepole pine with particular reference to British Columbia
C.C. Ying

E.P. 660
Trial of tree species and espacement in the Sub-Boreal Spruce Biogeoclimatic Zone
L.J. Herring

E.P. 662
An altitudinal test of a low elevation seed source of Engelmann spruce, Larch Hills and McGillivray Lake
G. K. Kiss

E.P. 667
Vegetative reproduction in spruce
R. van den Driessche

E.P. 670
Genetic improvement of interior spruces
G. K. Kiss

E.P. 671
Spacing trials in lodgepole pine
M.B. Clark, J. Pollack, L.J. Herring

E.P. 672
Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince Rupert plantations
G.K. Kiss

E.P. 688
Douglas-fir provenance plantations, Prince George Forest Region
L.J. Herring

E.P. 692
Shore pine spacing and provenance trial
C.C. Ying

E.P. 693
Testing selective herbicides for bareroot and container nurseries
R. van den Driessche

E.P. 695
Effect of planting season and stock type on lodgepole pine seedling performance
J. Pollack, G. Krumlik

E.P. 699
Propagation and evaluation of lodgepole pine breeding material
C.C. Ying

E.P. 702
Geographic variation in Sitka spruce
C.C. Ying

E.P. 703
Responses of immature Douglas-fir and western hemlock to thinning and fertilizer application
P.R. Barker, G.A. Godfrey

E.P. 705
Spruce Piceta, Chilliwack and Red Rock
G.K. Kiss

E.P. 707
A progeny test of coastal Douglas-fir using a factorial mating design with four male testers
J.C. Heaman

E.P. 708
Breeding program of coastal Douglas-fir
J.C. Heaman

E.P. 710
Interior Douglas-fir breeding arboretum
B. Jaquish

E.P. 711
Western larch breeding arboretum
B. Jaquish

E.P. 712
Tree species trial in the Kitimat Valley
J. Pollack

E.P 737
Cold storage physiology of conifer seedlings
W.D. Binder

E.P. 746
Physiological aspects of nursery production and field establishment of lodgepole pine, white spruce and interior Douglas-fir
A.N. Burdett

E.P. 747
Overwintering of conifer nursery stock
R. van den Driessche

E.P. 750
Yellow-cedar plantation at Cowichan Lake Research Station
I. Karlsson

E.P. 753
Nursery experiments with mineral nutrients
R. van den Driessche

E.P. 759
High elevation species and stock type trials
J.T. Arnott (CFS), F.T. Pendl

E.P. 764
Induction of dormancy and frost hardiness in western hemlock planting stock
W.D. Binder (ex. Cheung)

E.P. 770
Genetic improvement of lodgepole pine
M. Carlson

E.P. 771
Photoperiod extension for growth acceleration and flower promotion in lodgepole pine
M. Carlson

E.P. 773
Storage conditions and viability testing for coniferous pollen
J.E. Webber

E.P. 776
Correlations between quantitative and qualitative attributes
F.C.H. Yeh

E.P. 777
Rehabilitation of landings and skid trails in the Cariboo Forest Region
A. Vyse

E.P. 778
Experimental population genetics in conifers (Electrophoresis)
F.C.H. Yeh

E.P. 779
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Bergerud, W. (Wendy)	Biometrician	Victoria
Errico, D. (Darrell)	Technical Advisor, Biometrics-Experimental Design	Victoria
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Wrenshall, B. (Barb)	Data Control Clerk	Victoria
	SILVICULTURE	
Benskin, H.J. (Henry)	Manager	Victoria
Brockley, R. (Rob)	Assistant Silviculturist, Forest Productivity	Vernon
Cameron, I.R. (Ian)	(from Systems and Biometrics)	Victoria
Clark, B. (Bruce)	Forest Research Officer	Kamloops
Coates, H. (Harry)	Research Technician	Prince George
D'Anjou, B. (Brian)	Assistant Forest Research Officer	Vancouver
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Elmes, E. (Ed)	Research Technician	Kamloops
Geils, D. (Dale)	(from Systems and Biometrics)	Victoria
Goudie, J.W. (Jim)	Biometrician, Growth and Yield	Victoria
Gulsharn, M. (Megji)	Office Assistant	Vancouver
Herring, L. (Les)	Forest Research Officer	Prince George
Homoky, S.G.J. (Stephen)	Silviculturist, Rehabilitation	Victoria
Johnstone, Dr. W.D. (Wayne)	Silviculturist, South	Vernon
Krumlik, Dr. G.A. (George)	Silviculturist, Reforestation	Victoria
Letchford, T. (Tony)	Biologist	Red Rock
McArthur, S.N. (Stu)	Research Technician	Red Rock
Mitchell, Dr. K.J. (Ken)	(from Systems and Biometrics)	Victoria
Mitchell, W. (Warren)	Research Technician	Cariboo
Omule, Dr. S.A.Y. (Stephen)	Silviculturist, Growth and Yield Analysis	Victoria
Pendl, F. (Frank)	Forest Research Officer	Vancouver
Peron, M. (Michel)	Research Technician	Victoria
Pollack, J. (John)	Forest Research Officer	Prince Rupert
Polsson, K.R. (Ken)	Growth and Yield Analysis Assistant	Victoria
Romeo, M. (Maria)	Research Clerk	Prince Rupert
Sheran, F. (Frank)	Research Technician	Cariboo
Shishkov, G. (George)	Research Technician	Vancouver
Thompson, C. (Chris)	Forest Research Officer	Nelson
Van Thienen, F. (Frank)	Technician	Prince Rupert
Vyse, A. (Alan)	Forest Research Officer	Cariboo
Wray, P. (Pat)	Research Technician	Nelson
	TREE IMPROVEMENT	
Karlsson, A.I. (Ingemar)	Manager	Victoria
Andersen, S.A. (Svend)	Superintendent	Red Rock
Ashbee, D.P. (Doug)	Provenance Technician	Victoria
Atwood, L. (Lynne)	Research Technician	Vernon
Cairns, I. (Ian)	Nursery Technician	Cowichan Lake
Carlson, Dr. M. (Mike)	Tree Breeder, Lodgepole Pine	Vernon
Carson, D. (Don)	Superintendent Nursery and Camp	Cowichan Lake
Ferguson, D.C. (Craig)	Research Technician	Cowichan Lake

EMPLOYEE	POSITION	LOCATION
Ferguson, N. (Nellarene)	Receptionist/Clerk	Vernon
Franssen, G.J. (George)	Research Technician	Vernon
Hattie, R.N. (Bob)	Tree Breeding Technician	Victoria
Hayton, L. (Lisa)	Tree Breeding Assistant	Victoria
Heaman, J.C. (Chris)	Tree Breeder, Coastal Douglas-fir	Victoria
Jaquish, B. (Barry)	Tree Breeder, Interior Douglas-fir	Vernon
Jansen, H. (Henning)	Gene Archive Technician	Cowichan Lake
Johnson, E.M. (Ethel)	Tree Improvement Technician	Cowichan Lake
Kiss, G.K. (Gyula)	Tree Breeder, Interior Spruce	Vernon
Lee, T.E. (Tim)	Building Maintenance Man	Vernon
McLaughlin, S.D. (Shelley)	Research Technician	Vernon
McKnight, L.A. (Lesley)	Tree Breeding Assistant	Victoria
Murphy, J. (John)	Tree Breeding Technician	Vernon
Nicholson, K. A. (Ken)	Machine Operator	Cowichan Lake
Ogg, J. (John)	Propagation Technician	Cowichan Lake
Painter, A.J. (Tony)	Machine Operator	Cowichan Lake
Phillips, G. (Gisele)	Research Technician	Vernon
Pilcher, L. (Les)	Flunkey	Cowichan Lake
Pomeroy, N. (Norman)	Research Technician	Victoria
Ricketts, D.S. (Darlene)	Receptionist/Clerk	Cowichan Lake
Russell, J.H. (John)	Research Officer	Cowichan Lake
Wallden, D.R. (Dave)	Tree Breeding Technician	Vernon
Wilkinson, A. (Alan)	Cook	Cowichan Lake
Woods, J. (Jack)	Gene Archive Officer	Cowichan Lake
Woon, C. (Chio)	Tree Breeding Technician	Victoria
Yeh, Dr. F.C.H. (Francis)	Technical Advisor, Genetics	Victoria
Ying, Dr. C.C. (Cheng)	Provenance Forester	Victoria

TREE PHYSIOLOGY

Ebell, Dr. L.F. (Lorne)	Manager		Victoria
Baker, S. (Sue)	Research Technician	Research Lab,	Victoria
Balderston, M.B. (Mike)	Superintendent, Research Lab	Research Lab,	Victoria
Binder, Dr. W. (Wolfgang)	Physiologist, Nurseries	Research Lab,	Victoria
Burdett, Dr. A.N. (Nigel)	Physiologist, Nurseries	Research Lab,	Victoria
Calver, L. (Linda)	Receptionist/Clerk	Research Lab,	Victoria
Clark, J. (Joanne)	Lab Technician	Research Lab,	Victoria
Corck, E. (Ted)	Senior Lab Technician	Research Lab,	Victoria
Eastham, A. (Andrea)	Conifer Horticulturist	Research Lab,	Victoria
Gomez, J. (José)	Research Technician	Research Lab,	Victoria
Hedlin, D. (Doug)	Lab Technician	Research Lab,	Victoria
Hollefreund, C. (Clint)	Research Technician	Research Lab,	Victoria
Leadem, Dr. C. (Carole)	Tree Seed Physiologist	Research Lab,	Victoria
Liu, A. (Andy)	Lab Technician	Research Lab,	Victoria
Lort, J. (Jennifer)	Lab Technician	Research Lab,	Victoria
Martin, P. (Peter)	Research Technician	Research Lab,	Victoria
Mehl, H. (Helga)	Research Technician	Research Lab,	Victoria
Nassif, L. (Lois)	Research Technician		Victoria
Painter, R. (Roger)	Research Technician	Research Lab,	Victoria
Planden, R. (Ron)	Research Technician	Research Lab,	Victoria
Ponsford, D. (Dave)	Research Technician	Research Lab,	Victoria
Ralph, L. (Len)	Lab Technician	Research Lab,	Victoria
Ross, Dr. S.D. (Steve)	Physiologist, Tree Improvement	Research Lab,	Victoria
Shipton, G. (Glen)	Lab Assistant	Research Lab,	Victoria
Simpson, D.G. (Dave)	Tree Physiologist, Interior		Vernon
Vallance, A.M.E. (Marilyn)	Supervisor, Analytical Lab	Research Lab,	Victoria
van den Driessche, Dr. R. (Bob)	Senior Tree Physiologist	Research Lab,	Victoria
Webber, Dr. J.E. (Joe)	Physiologist, Tree Improvement	Research Lab,	Victoria
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Armleder, H. (Harold)	Wildlife Habitat Ecologist	Cariboo
Bancroft, B. (Bryce)	Resource Officer	Kamloops
Banner, A. (Allan)	Assistant Pedologist	Prince Rupert
Braumandl, T. (Tom)	Interpretation Forester	Nelson
Cheng, Dr. J. (Jack)	Hydrologist	Kamloops
Coates, D. (Dave)	Assistant Forest Research Officer	Prince Rupert
Coupé, R. (Ray)	Ecologist	Cariboo
Courtin, P. (Paul)	Assistant Pedologist	Vancouver
Dawson, R. (Rick)	Assistant Ecologist	Cariboo
Delong, C. (Craig)	Assistant Ecologist	Prince George
Doyle, K. (Kathy)	Research Clerk	Kamloops
Ellis, R. (Rick)	Manager, Wildlife Habitat	Victoria
Erickson, W. (Wayne)	Resource Officer	Kamloops
Faye, R. (Bob)	Assistant Pedologist	Prince George
Gluns, D. (David)	Assistant Hydrologist	Nelson
Green, R. (Bob)	Assistant Pedologist	Vancouver
Hamilton, E. (Evelyn)	Research Ecologist	Victoria
Holmes, D. (Doug)	Instructor	Prince Rupert
Hope, Dr. G. (Graham)	Assistant Pedologist	Prince George
Jang, L. (Lori)	Assistant Technician	Prince George
Jenveys, S. (Steve)	Assistant Pedologist	Prince George
Kassay, K. (Kathy)	Ecologist Assistant	Vancouver
Ketcheson, M. (Maureen)	Ecologist	Nelson
Klinka, Dr. K. (Karel)	Research Pedologist	Vancouver
Laird, R. (Robert)	Assistant Pedologist	Vancouver
Lindeberg, S. (Scott)	Assistant Pedologist	Prince Rupert
Lloyd, D. (Dennis)	Research Forester	Kamloops
Lousier, Dr. D. (Dan)	Ecology Program Manager	Victoria
Macadam, A. (Anne)	Assistant Pedologist	Prince Rupert
McKeown, K. (Karen)	Technician	Prince Rupert
McKinnon, A. (Andy)	Ecologist	Prince George
McLeod, A. (Angus)	Pedologist	Prince George
McNay, S. (Scott)	Wildlife Habitat Ecologist	Victoria
Meidinger, D. (Del)	Classification Program Correlator	Victoria
Meister, R. (Ron)	Assistant Pedologist	Cariboo
Mitchell, R. (Bob)	Pedologist	Kamloops
Moss, I. (Ian)	Assistant Interpretations Forester	Prince Rupert
Newman, R. (Reg)	Assistant Range Scientist	Agric. Canada
Nicholson, A. (Alison)	Ecologist	Victoria
Nuszdorfer, F. (Fred)	Research Forest Ecologist	Vancouver
Nyberg, R. (Brian)	Research Wildlife Ecologist	Vancouver
Nystedt, P. (Paul)	Botanical Illustrator	Victoria
Page, R. (Rick)	Wildlife Habitat Analysis	Victoria
Peterson, L. (Les)	Assistant Wildlife Habitat Ecologist	Campbell River
Pojar, Dr. J. (Jim)	Ecologist	Prince Rupert
Ray, C. (Cheryl)	Wildlife Habitat Ecologist	Campbell River
Roberts, A. (Anne)	Assistant Ecologist	Cariboo
Roddan, B. (Bruce)	Lab Technician	Kamloops
Russell, F. (Fraser)	Resource Officer	Kamloops
Sadoway, K. (Karen)	Assistant Wildlife Habitat Ecologist	Victoria
Saver, L. (Lynn)	Clerk	Kamloops
Scagel, A. (Anne)	Assistant Forest Ecologist	Vancouver
Schwab, J. (Jim)	Research Extension Forester	Prince Rupert
Spittlehouse, Dr. D. (Dave)	Climatologist	Victoria
Steen, O. (Ordell)	Research Ecologist	Cariboo

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Stewart, W. (Bill)	Research Technician	Kamloops
Still, G. (Gerry)	Pedologist	Nelson
Stordeur, L. (Linda)	Assistant Wildlife Habitat Analyst	Victoria
Thompson, C. (Carol)	Illustrator	Cariboo
Thompson, S. (Steve)	Assistant Pedologist	Nelson
Toews, D. (Dave)	Hydrologist	Nelson
Trowbridge, R. (Rick)	Research Pedologist	Prince Rupert
Warner, A. (Alison)	Ecologist	Nelson
Watt, W. (Bill)	Pedologist	Cariboo
Wikeem, B. (Brian)	Range Scientist	Kamloops
Wilford, D. (Dave)	Hydrologist	Prince Rupert
Williams, D. (Duncan)	Assistant Pedologist	Prince George
Yee, A. (Art)	Assistant Pedologist	Cariboo
Yole, D. (Dave)	Assistant Pedologist	Prince Rupert

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Archibald, G. (Gail)	Manager	Victoria
Appleyard, L. (Linda)	Records Clerk	Victoria
Chester, P.W. (Pat)	Senior Clerk	Victoria
Edgell, K. (Karen)	Clerical Assistant	Victoria
Gallant, D. (Denise)	Clerical Assistant	Victoria
Gronmyr, L. (Louise)	Word Processor Supervisor	Victoria
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